NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

REPORT OF COMMITTEE ON UNIFORMITY OF HOSE AND HYDRANT THREADS.

GEORGE A. STACY, MICHAEL F. COLLINS, LEWIS M. BANCROFT, COMMITTEE.

[*Presented September 14, 1905.*]

To the New England Water Works Association: The Committee on Uniformity of Hose and Hydrant Threads, appointed at the annual convention, held at Holyoke, Mass., in September, 1904, beg to make the following report:

Your committee upon taking up this subject realized from the first the many difficulties that surround the satisfactory solution of this problem. For thirty years spasmodic attempts have been made, from time to time, to establish a standard for hose couplings, and up to within a year (there being no coöperation and many of the attempts being without due consideration and study) very little progress was made. Your committee were agreed that there were three things essential for a standard thread:

First, it should be mechanically correct.

Second, it should be one that could be adopted by the principal fire departments, with the least trouble and expense.

Third, it should be such as would receive the endorsement of the fire insurance managers, commissioners and chief engineers of the principal fire departments; water works managers, superintendents, and manufacturers of fire department supplies and equipments.

The various diameters and pitch of threads used by the different fire departments throughout the country are almost equaled by

the variety of opinions as to what is best to adopt, but all are agreed that it is growing more and more important that a standard for hose threads should be established.

To collect and tabulate statistics necessary for the intelligent study of this question, to harmonize the various interests, and to secure their coöperation, required more labor and time than was at the disposal of your committee. We found that there were other committees in about the same position who were, or had been, considering this subject.

The Committee on Standard Thread for Hose Couplings of the National Fire Protection Association, of which Mr. F. M. Griswold is chairman, seems to be the Moses that is leading the various parties considering this question out of the wilderness of doubt and cross purposes to the light of corporation harmony, and a satisfactory solution of this problem.

Your committee desire to express their appreciation of the large amount of work done by Mr. Griswold, ably seconded by his colleagues, in collecting the information and tabulating the statistics from all over the country, whereby an intelligent study of the question could be made.

Your committee received an invitation last April to attend a conference in New York to consider this subject, but the notice was so short that none of the committee were able to attend. Later, by appointment, Mr. Griswold and Mr. Bruen had a conference with your committee at our headquarters, Tremont Temple, Boston, when they presented for our consideration a formula for hose threads and hydrant connections, together with facts and statistics by which they had arrived at their conclusions.

PROPOSED STANDARDS.

The following is the formula adopted by the National Fire Protection Association as a standard:

Inside diameter of hose, in inches	2½	3	3½	4½
Number of threads per inch	7½	6	6	4
***Male couplings:* Outside diameter of thread, *finished*, in inches**	3 1/16	3⅝	4¼	5¼
Diameter at root of thread, in inches	2.8715	3.3763	4.0013	5.3970
Clearance between male and female threads, in inches	.03	.03	.03	.05
Length of threaded male end, in inches	1	1⅛	1⅛	1⅛

The above to be of the 60° V-thread pattern with one one-hundredth inch cut off the top of thread and one one-hundredth inch left in the bottom of the valley in 2½-inch, 3-inch, and 3½-inch couplings, and two one-hundredths inch in like manner for the 4½-inch couplings, and with one-fourth inch blank end on male part of coupling in each case; female ends to be cut ⅛ inch shorter for endwise clearance. They should also be bored out .03 inch larger in the 2½, 3, and 3½-inch sizes, and .05 inch larger in the 4½-inch size, in order to make up easily and without jamming or sticking.

The following arguments were presented for the adoption of the above as a standard:

"*First.* The National Association of Fire Engineers' report for 1891 (Landy) shows a total of 1 339 towns using 2½-inch inside diameter hose couplings having outside diameters ranging, inclusively, from 3 to 3⅛ inches, and with hose threads covering from 7 and 7½ to 8 per inch; of this number about 70 per cent. can be made to be of reliable service with an outside diameter of 3 1/16 inches by the use of a tap or a die suited to the number of threads.

"*Second.* Messrs. R. D. Wood & Co. (1905) furnish statistics showing that in 811 towns the same conditions exist as to outside diameters and threads, and of these it is demonstrated that 52.6 per cent. could be adapted to the 3 1/16-inch outside diameter coupling by the same means as above.

"*Third.* A summary of 525 cases collated from a most exhaustive itemized list of couplings by Mr. J. R. Freeman, of the Factory Mutual Insurance Companies (1892), shows that 82 per cent. of that number carry the range of 7, 7½, and 8 threads to the inch, with outside diameters to couplings within the above limits, with such variations as promise an equal percentage of adaptability to the 3 1/16-inch outside diameter with 7½ threads to the inch.

"*Fourth.* As above noted, all couplings having an outside diameter included within the range of 3 1/16 to 3⅛ inches may be cheaply and easily made to conform to the 3 1/16-inch diameter by means of a tap or a die conforming to the size and number of the threads on the coupling.

"*Fifth.* It has been demonstrated that the swivel coupling, cut for 7½ threads to the inch, will make a satisfactory connection to the male ends of couplings cut to 7 and 8 threads where the outside diameter of each is 3 1/16 inches. To accommodate the swivel (female) end of the 7- and 8-thread coupling to that of the 7½-thread, an adapter would have to be used, and this, after

the adoption of a 'standard,' would mean limited expense, warranted by the conditions.

"*Sixth.* While there has always been divergence of opinion as to an accepted standard for hose couplings, the exigencies of the conditions have served to bring together many in authority who are now ready to accept the standard appealing to the best interests of all concerned, and this committee has assurances that whatever is acceptable to it will be accepted by them, and its adoption pushed with energy and persistence."

Your committee, in considering the formula and arguments presented, came to the conclusion that the formula very nearly conforms to the things which your committee consider essential and which were mentioned in the first part of this report, namely: That it is mechanically correct, and that it can be adopted by a large majority of the fire departments of this country with very little trouble or expense. Boston and a large number of fire departments throughout New England use what is called the Roxbury thread, which is $3\frac{15}{16}$-inch outside diameter and 7 threads to the inch; New York City and surroundings use 3-inch diameter and 8 threads to the inch; and so on throughout the country with different threads and diameters, but with the 7 and 8 threads for $2\frac{1}{2}$-inch hose predominating.

The adoption of $7\frac{1}{2}$ threads per inch and $3\frac{1}{16}$-inch outside diameter for $2\frac{1}{2}$-inch hose as a standard is a compromise or middle ground favoring no particular locality, and in the opinion of your committee, from their study of the question and their experience as heads of the fire departments of their respective cities in times past, will receive the endorsement and support of a very large majority of those interested.

In closing, your committee recommend to the New England Water Works Association for their endorsement the "National Fire Protection Association standard for hose threads," the formula of which is incorporated in this report.

DISCUSSION.

MR. STACY. The statement is made in the report that a satisfactory connection can be made by a $7\frac{1}{2}$, with a 7- or 8-thread on an emergency; that is, if a department with $7\frac{1}{2}$ threads was called to assist a city or town that had 7 or 8 threads to the inch, it

could make satisfactory connection. I can show you here an illustration of that fact. [Makes connections.] It is demonstrated that we can get turns enough on that thread to hold any ordinary pressure in coupling up a 7½ to either a 7 or an 8-thread, which is the practical argument in favor of this standard. This is a ground we can all meet on, taking the country as a whole. Of course we New Englanders, if we were just talking for ourselves within our narrow limits, would favor 7 threads to the inch, which the majority of us are now using; but when we take it on the broad ground of a national standard we cannot come to any other conclusion than that the 7½ thread is the proper thing and the wise thing and the least expensive thing which can be adopted by the departments throughout the country.

MR. F. M. GRISWOLD. *Mr. President and Gentlemen:* The matter of standardizing hose thread and hydrant couplings has been one of burning interest for the past thirty-three or thirty-four years, and, as the report of your committee has shown, the efforts to accomplish something have generally stopped with the making of the reports to the various organizations that have undertaken an investigation. The reports have been submitted and printed and that has been the end of them.

When the committee of the National Fire Protection Association was appointed to take up this subject, we felt its importance, and we thought we knew where the other people had failed, and consequently we immediately went to work to bring all you people in who are interested and find out what you knew and what you thought and get all of us working together. And the consequence is, I am very glad to say, that the American Water Works Association in May adopted the schedule which has been suggested by your committee to-day; the National Fire Protection Association adopted it in May; the National Association of Fire Engineers adopted it at Duluth, in August; the National Firemen's Association at Kansas City adopted it the latter part of August, when I was there; and, as your committee has said, 70 per cent. of all the hose couplings in the United States on 2½-inch fire hose can be connected, $3\frac{1}{16}$ outside diameter, 7½ threads to the inch. It has been demonstrated by Mr. Stacy here before you. We have a 7½ female coupling and a 7-thread and an 8-

thread, and they come together and make a mighty smooth joint when you come to handle them. It picks up the 7-thread a little more readily, as you see.

The insurance people have always felt that the interests of what might be called their own selfishness and the broad general interests of the public were alike. We want to see the possibility of Portland, Ore., helping Portland, Me., if it is necessary. It is a pretty long distance between the two places, but in 1873, when Chief Hill at Cleveland, Ohio, made the first proposition for the establishment of a standard he made the statement, " Gentlemen, I want a line of hose which will reach from the Atlantic Ocean to the Pacific Ocean with one standard coupling, and from the Canadian line to the Mexican line in the other direction." Let every man help his brother — and we all owe that duty to our brothers, gentlemen; there is no question about it. We ought not to stand on our own selfishness and on our own private opinion, but we should help our neighbors, and this is one way you can do it. We saw at Baltimore a few years ago the New York department, desiring to do everything it could to aid, come down there and have to tie its hose to the hydrants with wire and wrap the outside with gunny bagging, and they could hardly get water enough to make a stream, so that they were really of no service until they went to Jones Falls where they could get open suction. A little suburb near Baltimore could not be of aid because there was a difference in the hose couplings, and each community was important enough in its own estimation, before the fire came, to think itself "it." The only dividing line between St. Paul and Minneapolis is on the map; you can't find it on the ground. They both have 7 threads to the inch, but each has a different diameter. They are supposed to have adapters which will accommodate the hose of one city to that of the other, but when you come to investigate you find they haven't got them.

Now, after thirty-odd years of delay and hesitation, with graves strewn the whole length of time, the only inscription on the headstones being " inconclusion," isn't it about time that we should conclude something?

Now a word as to what has been accomplished. The city of St. Louis has 6 threads to the inch, and when this proposition

for a standard thread came up they were about placing an order for 40 000 feet of 2½-inch fire hose; and when it was decided by the National Fire Association that a 7½-thread, $3\frac{1}{16}$ outside diameter, was the thing, they said that was what they would have. They will change every coupling in that town where there are a million people and thousands and thousands of couplings to 7½ as against 6. When we went south to attend the meeting of the American Water Works Association last May, we stopped over in Washington. There is a very important bureau there some of us have heard from, the Department of Commerce and Labor, and one of the sections of that department is the Bureau of Standards, and Dr. Stratton is the man who is at the head of it. He had just returned from Paris and had got the metric system pretty well fixed in his head. When we showed this combination to him he threw up both hands and said, "That is an odd thread, 7½ inches." He took out his comparative scale and laid it down and said in surprise, "Why, that will accommodate itself to the metric scale within one two-hundredth of an inch. Now, if you can bring to us the approval of the leading associations of the United States which have the control or management of the water supplies or water use, we will be very glad to present a bill to Congress and have it passed, establishing 7½ threads, $3\frac{1}{16}$ outside, as the government standard." The government cannot compel this city or any city or section of the United States to adopt a standard of any kind, but it can give it the prestige of being the United States standard. And, further than that, if they adopt it as the United States standard it will spread itself throughout the world.

I am not only gratified but I am more than satisfied to feel that so important and intelligent a body as the New England Water Works Association should have received from its committee a report which in my judgment, is irrefutable; you can't get away from it. Now we have everything there is in the country.

MR. E. V. FRENCH. I do not think that I can add anything to the excellent description of all this work which Mr. Griswold has given. I think it goes without saying that a standard is in every way a desirable thing. The evils of the lack of it have shown themselves again and again in conflagrations where one

city could not help another; and it seems to me the work that this association has done along this line, and the work which Mr. Griswold has done, in bringing this matter to a head, not merely stopping with the report, but putting a very large amount of time into the thing, going before these different associations and explaining all these matters, has been exactly the thing which was necessary to bring the desired result about.

I am very glad that the committee of this association has come to the conclusion that this is a proper standard to adopt, and it seems to me that we have now really reached the time when it is sure to become a reality. I think we can all help a little in this way. Recently it came to our attention that one of the large companies was sending out hydrants to fit some of the older standards and were leading in the nipples. We asked them if they wouldn't be willing to screw those in, and then, perhaps, in a year or so, when the towns began to make a change, they could simply enlarge the old nipple or screw in a new one very readily. They replied they would be very glad to do that, but there would be a slightly increased cost. I think if each one of us would go home and urge the hydrant people and hose people to do everything they can to get in line for this change, it will all help to bring it around quicker, and it is certainly one of those things which the sooner it comes the better it will be.

MR. FRANK C. KIMBALL. In view of this report and the expert opinions we have had on it, I would move that the report be accepted and this standard adopted as the standard of the New England Water Works Association.

MR. FRANK L. FULLER. There is one matter that the committee did not speak of, which I suppose did not come within their province, but which, it seems to me, might well be spoken of at this time, and that is the way in which the hydrants should open. There is a diversity in that respect now, as you all know, some opening to the right and some to the left. It has occurred to me that perhaps the committee in continuing their work might make a recommendation in regard to that, and I should like to have that included in the motion, that they be asked to make a recommendation as to the way hydrants should open, whether to the right or to the left.

Mr. Stacy. I fully coincide with Mr. Fuller's opinion as to the desirability of having hydrants and gates all open in the same direction, but this committee has put considerable work into the subject that they were appointed to consider and have concluded their labors, and it seems to me it would mix things up a little bit now to bring in something that is foreign to the subject which they were appointed to consider. It would be opening up a new field at this time, the importance of which I acknowledge, and I would suggest that the work be carried on by some committee. But we consider that this report closes up and finishes our work, and we wait your approval of the work that we have done, and that will end the matter as far as this committee is concerned. Then if there is any new work to be done, — and there is lots of it of importance, — let us start afresh and have another report, but as chairman of this committee I shall insist that this report be considered as it has been submitted. You can either reject it or adopt it and that will end the matter, and then I would be very glad to see the suggestion of Mr. Fuller carried out, because there is nobody who sees a man on the other side of the street working away with a wrench and hollers, "The other way" to him, but wishes that everybody knew enough to open the hydrant the right way and that they all opened the same way. A man situated as I am, having the charge of the pumping engine as well as of the rest of the works, with the valves in the engine room turning one way and the valves on the street turning another, sometimes in the night, if he is a little sleepy, will have to scratch his head to think where he is. [Laughter.] But that is something which is foreign to the matter before us now, and I therefore shall ask for your verdict on our report as it stands.

Mr. Fuller. I simply mentioned the matter because it seemed to me that the two things were pretty intimately connected, and if the recommendation of the committee could cover both it would be a good idea. However, I don't want to impose any more work on the committee than they are willing to take.

The President. Then you will withdraw your motion?

Mr. Fuller. Yes; I will withdraw my amendment.

[Mr. Kimball's motion that the report of the committee be

accepted and this standard adopted as the standard of the New England Water Works Association was then put and adopted.]

THE PRESIDENT. Does Mr. Fuller want a committee appointed to consider the matter he has suggested?

MR. FULLER. I think this is a matter of a good deal of importance, Mr. President. In my own work I have always been confronted with the question as to which way the hydrants shall open. One man says they should open to the right, another man says they should open to the left, and, as I understand the hydrant men, about half of the hydrants open to the right and about half to the left. Now, it seems to me, it is time that the thing should be settled one way or the other. Personally it would not make any difference to me, as I know of, which way they opened, but, as Mr. Stacy has said, it is an abomination for a fireman to go out and have to be instructed as to which way the hydrants are to be opened, when it ought to be a commonly known thing and there should be uniformity everywhere. And while it seems to me that these two matters ought to go together, for the sake of bringing it before the association I will move that a committee be appointed to investigate this subject and make a recommendation. I understand any expression coming from this association would have a great deal of weight, and I am very sure that the hydrant people would be glad to have something adopted in the way of progress toward uniformity. Therefore, I make the motion that a committee of three be appointed by the President to make some recommendation.

MR. FRENCH. I would like to suggest in addition to that, that the committee also take up the question of the size and shape of nut, and I think it would also be well to include the ordinary gate valves, to see if we can't get the whole thing into one general standard. The National Fire Protection Association, as Mr. Griswold has just reminded me, are taking up both the question of hydrant stem and nut, and I am sure a committee of that association would be very glad to coöperate in work of this kind so far as possible; and I think it could be extended, as I say, to the gate.

MR. FULLER. I intended, Mr. President, to include the matter of the opening of valves, because I think they, of course, should open the same way as the hydrant.

[Mr. Fuller's motion was put and adopted.]

WATER-WORKS ACCOUNTING.*

BY JOHN F. J. MULHALL, PUBLIC ACCOUNTANT, BOSTON, MASS.

[*Read September 14, 1905.*]

Water-works accounting differs radically from accounting in other lines, excepting only gas, electric light, railway and telephone companies, due principally to the number and variety of the auxiliary books necessary for completeness of records as to revenues, operation, maintenance, and construction.

In order to treat this subject intelligently, it was deemed best to commence this paper on the assumption that a complete water works of modern type had been constructed, and was in readiness for operation, even though part of the paper might be considered as rudimentary in a gathering of water-works officials.

On the commencement of business, the public or quasi-public water-works corporation generally issues a pamphlet or flyer, embodying its rates, rules, and regulations, a copy of which is at the disposal of all citizens, and at the same time opens what is termed an —

I. APPLICATION BOOK.

BOSTON, MASS. ..... 1905.

CONSUMERS' WATER COMPANY.

The undersigned hereby makes application to the aforesaid company for a supply of water at (his or her) premises, located at ..... and occupied by ..... for ..... purposes only, and agrees to pay for same in accordance with the rates, rules, and regulations of said company, now or hereafter in force; and further agrees that the said company may enter upon the premises or any lands owned by ..... or in which ..... has a right, for laying all pipes that may be necessary for water-supply purposes, and that said company may inspect and repair such pipes at any time when occasion requires.

(Signature) .....

*Extract from a forthcoming book entitled, "Quasi-Public Corporation Accounting and Management," copyright, 1904–1905, by John F. J. Mulhall.

This is the authority or contract under which the water-works superintendent makes the service connection.

II. SERVICE CARD.

When the connection is completed, the service-pipe inspector makes out what is termed a service card, showing the size of the connection, kind and length of pipe from main to property line, with gates, etc., thereon; and on the back of the card showing a sketch or diagram of the connection. If desired, these data can be plotted on the large set of plans showing the system of works and connections therewith. If company charges consumer for tapping distribution pipe, or for the pipe from same to his property line, bill can be made directly from this card and proper record thereof made in the registers hereinafter described, after which the card can be filed.

III. PLUMBER'S CARD.

After the plumber has installed the fixtures in the house, he makes his return on what is termed a "Plumber's Card," showing for what purposes supply is used, and the number and kind of fixtures connected; also any fixtures or connections which may be used on the outside of the premises, and submits same to the company, whose representative makes an inspection of same and, if found satisfactory, countersigns the card. The details of the fixtures connected with the service can then be transferred to the inspection part of the register and card filed.

IV. WATER, TAP, AND SERVICE-PIPE BILLS.

All bills for water, taps, and service pipes are first entered in their respective registers. In order to avoid confusion and to expedite posting, bills for metered water, unmetered water or fixture rates, service pipes and taps, should be printed on paper of different colors. Bills are made with stub attachments, the stubs being retained by the collector as his voucher for moneys received.

The collector then submits his report to the treasurer or other officer, on a printed form arranged in a columnar manner, showing the number of service, name of consumer, amounts paid for water (meter and fixture basis separately), taps, service pipes, miscel-

laneous, and date when paid. The total of this report should agree with the total of the amounts as indicated on the stubs which he detached from the bills. When transmitting cash or check to the treasurer for the amount of the report with stubs attached, he receives from the treasurer voucher signed by him, which is made detachable from report by a perforated line.

Should the collections be made directly by the treasurer, he could make out a "statement of collections" on a form similar to the one described, and attach the stubs thereto, posting payments to the respective customers' accounts in the registers. The totals of the columns on these statements, viz., "Metered Water," "Fixture Rates," "Service Pipes," "Taps," etc., should also be posted to his cash account, under their respective columns, either daily, weekly or monthly, as the occasion demands, after which the statements can be filed. In a large works these statements should be written up and posted daily.

Another method is by th euse of a controlling account: At the end of certain predetermined periods to debit customers' accounts in the main ledger with the total amounts as shown by the respective registers for water, taps, service pipes, etc., and crediting these accounts in said ledger, also crediting customers' accounts and debiting cash when payments are made, and to make proper entries or allowances for all abatements, rebates, outstanding accounts, etc., at the end of the fixed periods.

V. COMBINED INSPECTION AND WATER REGISTERS.

The combined inspection and water registers, both for metered and unmetered water, are, outside the cash book, journal, and ledger, the two most important books of original entry in waterworks accounting.

The inspection part of the book will show all the details of each service, such as, service number, consumer, fixtures in use, meter number, size, kind, location, purposes used, etc., which have been transferred from the plumbers' cards. This part need be entered only once during the life of the book, which can be made to run for any number of years, preferably *five* years, on account of soiling from frequent handling. If there is a change in the fix-

tures or consumer, such change can be entered from the "House-to-house inspection" or the "On-and-off" book.

The financial part of the book is arranged in a columnar manner, having columns for amount due for water, service pipes, taps, miscellaneous, rebates, discounts or abatements, amount paid, when paid, and balance due for the unmetered register; for the metered register, reading cubic feet, difference, rate, amount due, discounts or abatements, amount paid, when paid, balance due.

By this method you will have at all times a complete record of each service connected with the mains, and its status, obviating the necessity of referring to other books when any question arises.

All bills should be entered according to the character of the service, either in the "metered" or "unmetered" registers.

When payments are made, the respective customers' accounts are credited in these books, and the totals are debited to cash under the respective accounts in the main ledger. At the end of any period, the total amount of payments should agree with the amounts received by the treasurer. These books are self-balancing, — the total amount of all bills rendered should equal the totals of the columns, rebates, discounts or abatements, amount paid, and balance due.

If the accounts are kept by the controlling method, the collections should be credited to their proper accounts in the main ledger.

For a large city, it would be advisable to divide the city into sections or wards, allotting books to such sections or wards in accordance with the policy adopted by the city, viz., whether payment for water is made on a metered, or fixture, room, valuation, frontage, or other basis, or combination of same, thus proportioning the books and work of accounting to different bookkeepers.

If desired, the columns for service pipes and taps could be eliminated from the above-mentioned books, and a separate book kept for these accounts, as charges seldom occur after the first installation, — then only for repairs or renewals.

VI. HOUSE-TO-HOUSE INSPECTION AND METER BOOKS.

These books are of such a common character that it is deemed unnecessary to make suggestions therefor. They can be printed and bound in a small book easily carried by the inspector, or else on loose leaves or cards and transcripts made directly to their respective registers; no entry or transcript is required to be made in the inspection part of the registers unless there is a change in the fixtures or name of customer. They should be arranged by streets or routes.

VII. ON-AND-OFF BOOK.

This can also be arranged in a columnar manner and kept on block form of loose leaves or sheets, manifolded, the manifold copy being sent daily to the bookkeepers to make proper entry in their registers of the services "on" or "off." If kept in a bound book, abstracts of daily changes should be sent to the bookkeepers.

VIII. CASH BOOK, JOURNAL, AND LEDGER.

These three books can be combined in one book for a small works, allotting the first part to Cash, the second to Journal, and the last part to Ledger, in the proportion of one half, one eighth and three eighths, respectively.

The journal and ledger are of the usual ruled form, but the cash book is arranged in a columnar manner, both on debit and credit sides, thereby making it a "Cash Ledger."

The following suggested headings or columns for a cash book are intended for a well-equipped works in a large city, — which can be added to or reduced to meet the needs of any works.

For Debit Side:

Water.							Meter Rentals.	Service Pipes.	Taps.	Expense.			Other Ledger Accounts.
Metered.	Fixtures.	Public Hydrants.	Private Hydrants.	Flushing.		Miscellaneous.							
				Streets.	Sewers.								

For Credit Side:

Expense.					Repairs and Renewals.							Salaries and Wages.					Fuel.	Taxes.	Interest and Discount.
Oil.	Waste.	Rent.	Insurance.	Miscellaneous.	At Pump. Station.	Mains.	Service Pipes.	Meters.	Reservoirs.	Filters.	Misc.	At Pump. Station.	At Filter.	At Office.	General.				

Construction.					Other Ledger Accounts.
Extension of Mains.	Service Pipes.	Meters.	Tools.	Miscellaneous.	

The totals of the respective columns, excepting only " Other Ledger Accounts " column, can be summarized at any given period, and posted by one entry direct to the ledger, thereby avoiding a great deal of unnecessary bookkeeping.

The column " Other Ledger Accounts " is intended for any personal or impersonal accounts with which it is desired to open an account in the ledger, and requires separate posting for each account entered in this column.

If payments are made by check, with voucher attached, columns can be inserted for "Voucher No." and "Total of Vouchers," if desired.

Another method is to open what is either termed a Distribution Book, Accounts Payable, or Vouchers Payable Book, in lieu of making distribution of accounts in the cash book, and make the distribution under the suggested headings for all disbursements; also open an Accounts Receivable Book, distributing the receipts under the suggested headings; and open controlling accounts with said books in the main ledger. This method is in use, as a rule, only in the largest quasi-public corporations.

IX. AUXILIARY BOOKS.

These books have only an indirect bearing on the revenues, operation, maintenance, or assets and liabilities of a plant; nevertheless they are important as a means of ready reference, and should be kept by all works.

(*A*) *Construction Record Book.*

This book, as its name implies, shows size, kind, lengths, and location of all pipes, hydrants, valves, valve boxes, meters, etc., which are buried in the ground to a great extent; and details and sketches of other structures, such as pumping stations, reservoirs, standpipes, filters, etc., culled from the original specifications or contracts for building the same. It contains all information which a general plan of the works should furnish, but in addition gives the details on all parts of the construction. It is assumed, however, that all works would at least have a general plan showing the pipe system and connections.

Information of this character should be a matter of record, for in case of absence, disability, or the sudden death of a manager or superintendent of a plant, who alone was the possessor of these data, emergencies might arise, such as a break in the mains, which might cause loss by flood alone running into the thousands of dollars. As a means of ready reference, alone, it will economize in time and labor, and at times avoid large financial outlay to properly locate the pipes and other structures which have been buried in the ground for years.

For a large city it would be advisable to have a construction record book covering the whole city; and in addition thereto, sectional or divisional construction record books, each superintendent of a division or section being furnished with a copy of the construction records pertaining to his division.

(*B*) *Gate Book.*

This book is in the nature of a small sketch book, which can be carried in the pocket, showing the location of gates and hydrants by streets, and is invaluable to a superintendent, as it obviates the necessity of consulting the plans continuously. If more than one copy of the book is desired, the original sketches can be made on tracing cloth, and blueprints made therefrom at a small expense for any number of books. They should be indexed by streets. For large works, gate books should be allotted to each division or section.

(*C*) *Pumping Station Record Book.*

This is kept by the engineer or his assistant, and shows the time of pumping, number of revolutions of the pump, kind of coal and amount used, number of gallons of water pumped daily, etc.

Computations from these data can be made which will show the amount of water pumped during the year, either by water or steam power, and whether the pump is performing duty equivalent to its rated efficiency. If not, there is a loss in delivery, which is commonly called " slip," and it would be advisable to have the pump tested and put in repair, thereby keeping down operation charges in reducing the amount of coal consumed,

wear and tear on pumping machinery, and additional cost of extra engineering force.

(*D*) *Filter Record Book.*

This book is kept by the operator at the filter plant, in a columnar manner, with columns for day of month, duration of pumping, head on filters, before and after using, number of filters in use, water filtered in twenty-four hours, average rate of filtration per filter, amount of water used in washing filters, amount of alum used, other chemicals, compartments cleaned, turbidity, temperatures (air and water), results of analyses, and column for remarks, under which can be entered such data as when filters were replenished and washed, number of men employed, teams, etc.

(*E*) *Meter Test and Meter Repair Books.*

These books are more in the nature of records of the comparative efficiency and durability of the different kinds of meters on the market, and can be arranged in a columnar manner, showing the kind and size of meter, maker, head, openings or size of streams measured, discharge (cubic feet), percentage of loss on rated efficiency, etc., with column of remarks, under which can be entered the conditions under which the test is made for the meter test book.

For meter repair book, columns for date set, maker, kind and size of meter, date repaired, with extended column for repairs and renewals, sub-divided into columns for spindles, disks, casings, frost cases, bolts, etc., following with columns of cost and remarks.

These books can be made up in bound form, loose leaves, or the data kept on cards, as seems most desirable.

In conclusion, I would state that the greater part of these books, excepting only a few thereof, have been in use for the past twenty years by Messrs. Wheeler and Parks, — latterly Mr. William Wheeler, who purchased Mr. Parks' interest, — large owners and operators of water works throughout the United States, with whom I have been engaged during that period.

DISCUSSION.

MR. W. C. HAWLEY.* The paper presented by Mr. Mulhall certainly outlines an admirable way of keeping the accounts of a water department or water company, but there are one or two things which might be of considerable value in addition. I find that when we have an argument with some of our consumers, sometimes there is a great reluctance on their part to accept a record which one of the employees of the water company has made, as to turning off the water, turning it on, repairs, etc. Doubtless some of you other gentlemen have come across that same condition. If you have to go into court with your books, you will find even a greater reluctance on the part of attorneys and juries to accept such evidence.

For that reason our company has prepared a set of books, in the form of orders, — one book for turning on, one book for turning off, another book for meter repairs, service repairs, and so on, covering all those things for which we may have to charge and of which we want a record. The consumer's signature is required on those orders. The various original orders are printed on different colored papers, and the orders are in triplicate, the second and third being carbon copies. One carbon copy remains in the book as a record, the second carbon copy goes to the foreman of the proper department, and the original remains in the book until the foreman has made his return and has entered up his record on it and then it is filed with the original contract in the contract file. At any time when we wish to know the history of the contract we can turn at once to it and there are the original papers with the signatures of the consumers, which we find very much better evidence than simply a record in our ledger, for instance, made by a clerk.

I had an illustration of that recently when a lady with one of those automatic ball-bearing tongues came in and spent nearly an hour telling me her troubles. I was at a loss how to settle the matter with her, until one of our clerks who overheard the argument happened to go to our contract file — it isn't all completed, we only have part of it ready — and fortunately found that this

* General superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

particular contract had complete records with it, and I was able to show the lady that on the day she said she had ordered the water off she had really signed a contract and an order to turn it on. On the day she ordered it turned on, according to her story, she signed another order to have it turned off. It didn't take long to settle the matter then. Such a record is of very great value.

MR. MULHALL. I will say that this paper of mine is intended as a rough draft, a sort of groundwork, as it were, for water-works accounts. It would not cover the case of some city where the ordinances, or their desires, might require the on-and-off book or other books to be kept separately. This is condensing matters into the smallest number of books, which I find to be the desire of water-works people as a rule. A book could easily be made for the "on" services and another for the "off," or a book could be arranged, the first part of it for the "on" and the latter part of it for the "off," and as the customers have to sign the book they would have to come to the main office.

I will say further that the cash accounts which are recommended would not apply to small works, because they would involve too much bookkeeping. They would have to use their own judgment as to what accounts they wanted to open so as to reduce the work to a minimum.

MR. A. A. REIMER. I should like to ask Mr. Mulhall what he has found the opinion to be regarding the keeping of records by the card system rather than by the loose ledger or open ledger plan?

MR. MULHALL. Well, being an accountant, I must say that I should be entirely opposed to the card system for financial records; I would not for a moment recommend cards for people to keep their financial data on, — my reputation would be at stake.

In the first place, supposing you do use cards, you have got to buy office furniture which takes up considerable floor space for a large concern, floor space for which rent ranges from $1.50 to $3.00 per square foot in the large cities, and if capitalized at 4 per cent. would amount to a great deal of money, which is equivalent to an original investment of that amount. You really have to buy

special furniture; cards are common and you can buy those anywhere. So much as to the first cost.

Now, coming down to cards as a matter of keeping records,— it means you have to find the proper card in the bunch, take it out, put it on the table, fill your pen with ink and write on it, then blot it, put your pen down and put your card back in the place from which you took it. All that takes a great deal of time, and if time is worth anything you shouldn't use it in that way. I know the card system was installed in some places and taken out again. The Chicago Gas Company put in the card system and got tired of it; the Lawrence Gas Company and the Somerville and the Malden Electric Light Company, I understand, and the Walworth Manufacturing Company, and Lowell Machine Shops. I would add here that the Walworth Manufacturing Company did not install it with reference to their financial affairs but only to keep tabs on different pieces of fittings and things of that nature.

I think cards are excellent for records of service pipes, plumbers' work and possibly meter records, and things of that sort, where there are no financial data connected with them. Cards can be lost and the loss of one may throw your whole accounting system out of gear. Then consider the question of the possibility of theft, and getting rid of cards to destroy evidence. The card system is accepted in court as a matter of record when there is nothing else available, but it hasn't the standing a bound book has, and in fact it hasn't the standing of a loose leaf. There is a great force back of the card system, I mean a financial force, but very few accountants recommend it. I have never known one who did. In fact, I have only known one accountant to recommend the loose-leaf system, but the loose-leaf accounting has many valuable points in its favor. It is not so easy to lose a leaf as it is to lose a card; and audits and totals can be secured a great deal quicker. All the advertised advantages, however, of both the loose-leaf and card system can be incorporated in bound books. Cards are entirely out of the question with me, anyway.

Mr. Reimer. I thank the gentleman for the information, but I may say that in the department with which I am connected we have had a great deal of success with the card system in both

the financial and the operating departments. I know that the clerks in my department would not have anything else if they could have their choice. As regards the opinion of experts, the department has been recently audited, and in their report the experts most heartily favor the card system and advocate it very strongly for the water department, — that one department of the city only, but very strongly for that department. I wanted to state what our experience had been in case others were contemplating the use of the card system.

Mr. Kenneth Allen.* I may say that the city of Baltimore uses the card system entirely in its water accounting, and I understand it has been found to work very satisfactorily there. We use it in Atlantic City only for the record of services, and have just introduced it for keeping a sort of stock account, so that we can destroy the cards when they are used up. That is, when we have filled the card we transfer to another card and throw the old one away. For the keeping of ledger accounts I think there are some strong arguments in favor of the old book systems.

Mr. Edward W. Bemis.† The card system as a method of keeping the accounts of the meter departments of a water works has been challenged. I rise not exactly to pick up the gauntlet, because I do not claim to be an expert accountant, but I will state that the Cleveland Meter Department is entirely on the card system, with the exception of certain books of the double entry system, which fits into the card system, and which was adopted and worked out for me by a member of the Ohio Accountants Association, Mr. Carl Nau, now of Cleveland, who is recognized as one of the best accountants in Ohio. He states that the system which he has worked out to supplement the card system has made it absolutely safe. Other investigators, such as the state of Ohio supervisor of municipal accountants, who is a part of the state auditor's department, — Ohio is the only state in the Union except North Dakota which has a supervision of all the municipal accountants, — he has looked into the matter to some extent and considers that we have an entirely safe system. The details of it I will not go into. I think I will ask Mr. Carl Nau to

* Superintendent of Water Works, Atlantic City, N. J.
† Superintendent of Water Works, Cleveland, Ohio.

prepare a statement and I may send it on to be read at some future meeting, if he cannot attend. It will explain why it is considered a safe system.

In the matter of economy of time, I may say we have saved a great deal. You see we are metering so rapidly that it is a great convenience at every six months term to put in the new cards by streets and by the particular location on the streets. We had 30 000 meter cards the first of April, and we will add 10 000 more the first of October, owing to the results of our meter setting the last six months, and we want to put them in the order of location. We have several checks on this. For example, we have a book record of every connection in the city, and we audit the card system every little while by this record of the number of connections. Then we have the meter reading books as another system of auditing. Then we have the stubs of all the meter bills in the auditor's office, which is another system of auditing. And we have set up a system of double-entry bookkeeping, with a competent bookkeeper in charge, in connection with this card system, each street, I believe, being reckoned as a separate account and all the cards on that street being charged up in the account and then audited. The whole system has to be audited by streets every term. I am not sufficiently familiar with all the details of the system to be able to defend it against such an expert accountant as has attacked it this morning, but I thought I would merely say that I do not think we are yet the awful warning which it has been said that those cities which adopted it would be, and I especially wanted to say that the system does have the approval of very eminent authority, and was, in fact, worked out by one of the best expert accountants in the West.

Mr. Mulhall. Mr. President, I acknowledge that the card system for certain purposes is very good, such as keeping meter records and service-pipe records, or anything which does not bear upon the financial data; but as a rule, and I think the best practice and experience bear me out, in very few cases is the card system used for financial records. Very few quasi-public corporations are on the card system. They are generally either on the bound book or the loose leaf. The New York Gas Company and Electric Light Company would no more think of using the card

system than — well, than I would. The Providence Gas Company would not tolerate it. The Portland Gas Company had cards in and took them out; the Chicago Gas Company did the same thing.

Now, I haven't looked up the reasons why they took them out, because I am satisfied in my own mind that it takes about twelve to twenty times as much work for a bookkeeper to handle the card system as it does the bound book or the loose-leaf system, for the simple reason that you have to take a card out every time you make a record, and put it on the table, blot it and put it back. That is for just one record, there being only one account to each card.

Now to get up monthly statements, by the bound book or loose-leaf system you can add up the accounts of from 20 to 50 customers at once to get the monthly total; if you have the card system, where there is a large number of customers, you would have to take out each card and either call it off to a machine operator or jot the amount down on a piece of paper, which increases the liability of error proportionately to the number of times handled. To get the accounts to balance they sometimes have to go over it two or three times. Card accounts, furthermore, are not self-balancing.

I know of a case at the present time, I am not at liberty to state where it is, where they have adopted the card system, and they have about 120 000 customers, and they are at sixes and sevens now. The parties who introduced the system had their representative there looking out for it for about a month. The cry in the office is, "Put the card back in its proper place always." "Don't touch that box." "Don't take that card out." There are 120 000 customers and about 100 or possibly 150 clerks, and think of the possibilities of cards being taken out and mislaid or lost, especially when they are handled by so many clerks.

It takes a larger force to handle the card system, and the expenses of the extra force of employees necessary, together with the cost of adding machines and renewals thereof, should be capitalized in arriving at the first cost, in addition to the floor space previously mentioned.

I was talking the matter over with the treasurer of a large gas and electric light company, who were on the card system, one

day, and he said, "Well, there are a great many things against the card system; what you told us is true." They all acknowledge that they lose or mislay cards at times, and the loss of a card is an occasion of sorrow to the treasurer or to the financial man in charge of the department.

But supposing they don't lose cards. It takes them, as I said before, a greater length of time to add up the total customers' bills for a month or day by the number of times they have to handle the cards and put them back. They are not self-auditing.

I have got some objections here, while I think of it. The treasurer of a large gas company suggests these objections:

1. Only one account to a card.
2. Harder and longer operation to post. Work in ratio of 20 to 1. (He says 20 to 1; I said 12 to 1.)
3. Not self-auditing.
4. Not approved by auditors.
5. Longer time to get totals.
6. Danger of misplacing or losing cards.
7. Can't put in ordinary vault.
8. Numerous and expensive filing cases for present and future use.
9. First cost of fixtures, of files, etc., excessive.

Now, I didn't think this subject was coming up here, but I happened to have these data on hand in my memorandum book.

Another case I know of where a party is enthusiastic over the card system. He has put in one vault which cost him about $500 and he is going to put in another vault to cost $500 more, to take care of a few more cards. Books could go into the vault all right, books can be arranged for a vault. You are not liable to lose a whole book at once; you are liable to lose a card. I will acknowledge what the gentleman said. He will find some people who will recommend it to a certain extent, but not for financial data.

MR. BEMIS. Mr. President, I am delighted to have these things brought out, for nothing can do us more good than to have all our positions challenged, and it will furnish the basis, I hope, for a further discussion at some future meeting. I will merely say that in the year or two this system has been on trial with us

not a card has been lost. There are only a dozen clerks who have access to these 40 000 cards. And as to the matter of time, I am sure we manage it so that we gain time rather than lose it. Addition may not be quite as quick although with the adding machines it is very rapid. But where we may lose a little in that we gain in the ability to refer readily. Every day in the collection department there are large numbers of people who want further information about their bills, — we sometimes have complaints about them, — and we can instantly produce the card which has on it the last meter reading, the present meter reading, the amount of water used between, and the bill made out on that basis. That is all on one card. And we have on the same card the previous bills running back from one term to seven or eight. And if we want to go back further, if the card in use does not go back far enough, we can go to another section where we have the previous card. I think the gain in ready reference in answering questions and complaints of consumers is enormous, and in the opinion of our clerks who have worked under both systems it more than counterbalances the slight loss there may be in addition. And, further, I will say that our accounts balance to a penny every six months thus far; how it will be hereafter remains to be seen. I merely want to state that there is more possibility of using the card system satisfactorily than perhaps might have been inferred, although it must be supplemented by a controlling account set up on the general ledger of the department and be a part of the comprehensive double-entry bookkeeping system.

RELATION OF INTENSITY OF TYPHOID FEVER TO CHARACTER OF WATER CARRIAGE.

BY PROF. W. P. MASON, TROY, N. Y.

[*Read September 14, 1905.*]

Typhoid epidemics following the use of polluted river water are commonly mild in character, while isolated country cases of the disease are often severe. Such has been the writer's experience, and a reasonable explanation would seem to be that while the adverse conditions of river carriage supply abundant opportunity for the pathogenic germs to either die, or to at least lose a portion of their virulence, the conditions governing the use of water from an infected well usually admit of a shorter period of time elapsing between the entrance of polluted material and the drinking of the water. In other words, the struggle for existence during stream transmission will cause a decrease in the "poisoning power" of the typhoid germ, which decrease will vary directly with lapse of time, and will consequently be a function of both distance and velocity of flow. Bacilli, therefore, which started on their journey in vigorous health might be considered as arriving at the point of invasion in a state so enfeebled as to be incapable of producing a "normal" type of disease.

Such a proposition was advanced by the writer some two years ago in an important case involving the question of water-borne typhoid, and the following data are offered in support of the argument.

At Waterville, Me., there recently arose an opportunity to study an outbreak of typhoid fever occurring among people who used waters of widely different characters. The public supply of the city was from a stream which received the sewage of a town a few miles away, and many cases of typhoid occurred among those who exclusively used such water. Throughout the town there were numerous grossly polluted domestic wells, and fever cases were plentiful among families using water from no other

source. As was to have been expected, a still larger number of cases of the disease were found where the water drunk was from both the wells and the river. A careful house-to-house visitation elicited the following data. The division of the cases into "light" and "severe" rests upon the statements of the attending physicians.

Water Used.	Number of Cases.	Light Cases.	Severe Cases.	Ratio of Severe Cases to Total Cases.
Stream	61	44	17	27.80%
Well	46	20	26	56.50%
Mixed	132	72	60	45.45%

Data such as the above are very difficult to secure, and we are usually forced to rest satisfied with mortality returns alone, but even from such unsatisfactory material our proposition receives no small measure of support.

In a report prepared for the Parliamentary Bills Committee of the British Medical Association, Hart gives sundry figures for a number of British epidemics of typhoid fever. It is possible to pick out from his collection of facts 108 instances where the disease could be traced to contaminated wells upon the one hand, or to polluted reservoirs or streams upon the other. The table here following gives the average death-rates for the two classes of epidemics, and there are added the figures for milk epidemics also, although such are foreign to the present discussion.

	Average Death-rate.
75 epidemics due to well waters	11.83%
33 " " " stream and reservoir waters . . .	9.85%
20 " " " milk	12.79%

In speaking with the writer upon this general subject, a Philadelphia physician of large practice said that his typhoid death-rate in private practice was about 5 per cent., but that upon one occasion it was much higher. He was called to attend an outbreak of the fever occurring among a considerable number of Russian sailors, who had been sent to Philadelphia to man a battleship then building at Cramp's shipyard. These men drank water from a well which was afterwards proven to have been grossly polluted. The typhoid death-rate resulting among them was about 20 per cent.

Such figures as have been given certainly tend to show that greater or less concentration of polluting material and longer or shorter exposure of the typhoid germ to unfavorable surroundings must be held to account in part at least for the variability observed in the intensity of the disease.

One word further, if I may be pardoned for taking your time. I have seen quite a number of figures of recent date with reference to typhoid fever, notably those from the city of Columbus. Both the number of deaths and the number of cases were reported monthly. It was peculiar to observe that when typhoid was not very prevalent in the city the death-rate was very high — most of the patients died; but when typhoid fever was really widespread and there was an epidemic, most of those attacked got well. That merely shows, of course, that when there is but little doing in the matter of typhoid the cases are not reported. Physicians will report cases during an epidemic, but they will not report them during a non-epidemic period unless they should happen to be fatal.

DISCUSSION.

Dr. George A. Soper.* Dr. Mason has brought together a number of convincing statistical facts which confirm a view which, as he says, is not entirely new, having been pronounced by him some years ago, and which has been, I fancy, very generally accepted. Much credit is due him for gathering these statistics which he has cited. Statistics of typhoid are exceedingly difficult to collect. Even under the best circumstances, it is almost impossible to tell how many cases of typhoid occur in any epidemic; and during the times when there is no epidemic, it is practically impossible to know even approximately how much typhoid is at hand.

Dr. Mason has struck a note in his concluding remarks which, I think, we should all take particular notice of, and that is that physicians are so often delinquent in reporting their cases. I think we all ought to insist, when cases of typhoid fever come under our notice, that they be reported. In no other way can the prevalence of typhoid fever throughout this country be brought finally under control.

*Sanitary Engineer, New York City.

I have a few facts which confirm Dr. Mason's argument that typhoid fever which has been produced by drinking infected well water may be more severe and more fatal than typhoid fever brought by water from a distance. In a paper which I read at the last convention of this Association upon the epidemic at Ithaca in 1903,* I mentioned that the epidemic was exceedingly widespread through the city and that the death-rate was about 7 per cent. Towards the end of that epidemic, — in fact after it had ceased, — there was a sudden outbreak which was traced to a well. In that instance every case of typhoid fever was extremely severe and the death-rate was 10 per cent.; fifty people were attacked and five died. The person who infected the well had a very mild case which was contracted from the water supply.

There are probably excellent reasons why the disease is more intense when the germs have only recently passed from the sick. Laboratory experiments and field experience indicate that the germs become attenuated by remaining a long while outside of the body under unfavorable conditions, and so lose their power of producing the typical form of typhoid fever which can easily be recognized by the physician. At the same time, it must not be forgotten that all of the diarrheal diseases which occur in an epidemic are not, in all probability, due to typhoid germs. The same conditions which lead to the infection of a water supply by typhoid bacilli are likely to lead also, and at the same time, to its infection by germs of other enteric disease. In any large epidemic, therefore, it is not improbable that we have to deal not only with typhoid but other enteric diseases which pass for typhoid. This may account in part for the comparatively low mortality in some typhoid fever epidemics, traceable to public water supplies. When a well becomes infected with typhoid bacilli, it is not so likely that the germs of other enteric disease are present also.

It is a matter of doubt, in my mind, whether the length of time which the bacilli have spent in passing from the sick to the well is the main element in reducing their vitality. The time at Ithaca and Watertown seems to have been as short as in some well epidemics. At Ithaca the infectious matter which produced the epidemic could not have traveled more than twenty miles,

*JOURNAL, December, 1904, vol. 18, p. 431.

and it passed over this distance at a time when the stream was in freshet. It was probably a question only of a few hours from the time when the infectious material was let loose to the time it reached the intake of the water works. At Watertown the nearest village was 4½ miles away, and the farthest from which the infectious material was believed to have come 17 miles, and the water supply in this case also became infected during a freshet. It is probable, therefore, that in these two extensive epidemics the infectious material was only a few hours in passing from the place where it originally lodged to the water works. It is true, however, that we do not know how long a time was actually consumed by the bacilli in their passage from the sick to the well in these instances.

With respect to the difference between the mortality among the Russian sailors and among the private patients of the physician in Philadelphia, I think the care that the different people received may account for a good deal of the astonishing difference in the death-rate. Care in typhoid fever is the best cure we know. Among people who can afford the very best nursing, the death-rate is lower than among others. Among sailors the death-rate from typhoid seems always to be exceptionally high.

Mr. F. A. W. Davis.* Mr. President, while I of course believe everything that the experts say, I should like very much if they would turn their attention to fixing definitely, if they can, if there are not other means of spreading typhoid fever than through water, although I suppose we must confess that water is the largest carrier of typhoid fever. We are very much interested in this question in Indianapolis, and we have spent considerable money and time in the investigation of it; and we are satisfied that we are still a long way from ascertaining the exact causes of the spread of typhoid fever.

Dr. Mason. Of course, as we all know, a very considerable amount of typhoid fever is capable of being transmitted by flies. A ponderous tome has recently been issued, published by the Government, the main subject of which is typhoid fever during the Spanish-American war. The surgeon of one of the New York regiments has told me a pretty grewsome tale about the

* President Indianapolis Water Company, Indianapolis, Ind.

spread of typhoid fever by flies, and he is a man who knows what he is talking about.

With respect to other modes of transferring typhoid fever from person to person, there is the mode of secondary infection which is referred to so often by Sedgwick in his reports, where filthy surroundings allow filthy people to have their filthy hands come directly in contact with food. So far as milk epidemics are concerned, of course they are water epidemics after all, because they result from the filling of milk into cans which have been washed in polluted water.

One word more, if I may be permitted. I do not wish to lose sight of the main distinction between 20 per cent. and 5 per cent. in the death-rates to which I have referred in Philadelphia. Dr. Soper in his remarks has said that a great deal depends on the nursing. That is true, but you must remember that these two death-rates were in one man's practice. That is an important fact to be borne in mind. And while those Russian sailors were doubtless not the richest people on earth, they probably had excellent care, for Russia was paying the bill.

MR. M. N. BAKER.* The incompleteness of our typhoid statistics is notorious and extremely unfortunate, and we certainly should, all of us, use our influence to the greatest possible extent to make these statistics more complete. It would seem as though physicians above all men would be greatly interested in reporting cases of illness and death from the various communicable diseases. But I know from my experience in the last ten or twelve years as a member, and, later, as president of the board of health in a small town, that even where there is, as there is there, a very intelligent body of physicians, a body which is very glad to coöperate with the board of health and is continually coöperating with it in all respects, we have difficulty in getting prompt and complete reports.

In the matter of typhoid fever, however, I think our reports are quite complete, as we were unfortunate in years past in having some serious outbreaks of typhoid, thus impressing upon the physicians the importance of prompt and complete reports. One of the worst of these outbreaks emphasizes a point suggested

* Associate Editor, "Engineering News," New York City.

by one of the previous speakers. It was an out-and-out milk epidemic. In a town which then had a population of perhaps 11 000 or 12 000, we suddenly had 80 typhoid cases, followed by 13 deaths. All the cases were found after careful investigation to be attributable to the milk that came from a single dairy. The cans used for handling this milk were washed with the water from a well, which well was not very many feet distant from an outhouse at a higher level than the well; and this outhouse, it was subsequently ascertained, had been used by a young man, a son of the milkman, who had what may be called a walking case of typhoid, in fact I think it did develop into something more serious than a walking case of typhoid.

While we must not relax our efforts to safeguard our water and purify it when needed, it is important to all who have to do with the management of water works and the reputation of water works, that they should try to bring pressure to bear upon physicians and upon local boards of health to get more accurate and more complete vital statistics. We should not stop short with trying to see what part of the typhoid in a community is attributable to the public water supply.

One way in which I think we will have to broaden our health protective work is to include in our studies of typhoid hereafter, if we can find it feasible and practicable to do so, studies of the diarrheal diseases. I am convinced that while such studies will prove quite difficult, and the results may perhaps be ambiguous for the present, they will do this, if nothing else: they will show that in many of our communities diseases which really are typhoid are being reported as something else; and a careful comparative study of the diarrheal diseases in a given community, in connection with the returns for the same classes of diseases in other communities, will gradually throw a great amount of light upon this question and will contribute to the completeness of our typhoid statistics. I have recently had occasion to go over the vital statistics of a city which now has a population of nearly 20 000, for some twenty-five years past, and there are some things in connection with those vital statistics which are really very surprising, and which some day it is possible I shall have the pleasure of laying before the association.

MR. GEORGE W. WRIGHT. Getting back to Professor Mason's remarks on the relation between typhoid from well and stream waters, in the city which I represent, Norfolk, Va., we have had no typhoid cases from the city water, that is, none have ever been differentiated by the city bacteriologist. We have quite a number of typhoid cases in the city, and they are accounted for by the fact of the large floating population, and that there are many people who live at the beaches during the summer who, as a rule, drink water from wells, and it is claimed that they bring most of the cases to the city. That is the principal reason, I think, why we have a comparatively large typhoid fever rate in the city of Norfolk, and it is not due to the city water at all. With reference to the virulence of different cases, those who come from the beaches usually have severe cases, which would seem to bear out Professor Mason's theory.

DR. SOPER. Mr. Baker has said that it is well worth while to investigate and take account of the diarrheal diseases which are not positively pronounced to be typhoid, because he thinks that in many cases such diseases will be found to be typhoid. This is precisely my own view. The fact that a great deal more typhoid fever exists in any locality, where some cases are known, has been very conclusively settled by an investigation made by Koch, who embodied the results of his study in a lecture which he delivered before the Kaiser Wilhelm Academy, Berlin, November 28, 1902.

I have no doubt that before many of the great typhoid epidemics have broken out, there have been distinct warnings in waves of diarrheal diseases that have passed over the communities and that these signals of danger could have been discovered and interpreted by any one who had the disposition to note them. At Ithaca there was the well known "Ithaca fever" or "Freshman fever," which attacked large numbers of the freshman class at Cornell University every year. When the typhoid epidemic broke out in 1903, it was at first declared to be nothing but the "low form of fever" which had been experienced every year in the fall. At Butler, Penn., small waves of typhoid had passed over the city before the great epidemic of 1903–4. At Watertown, N. Y., several distinct and recognized epidemics occurred before the extensive outbreak of 1904.

The warning signals of typhoid epidemics are probably flying in many cities to-day. It behooves water-works people to look for them and when discovered to take those measures of precaution which alone can be successful in averting disaster. It is unnecessary to point out the nature of the precautions. The conservation of the purity of the water supply by the sanitary protection of the water-sheds, and the purification of waters of doubtful quality by means of filtration, are among the most firmly established measures of safety which experience offers. That such work must be done in the best possible manner, if done at all, it is not necessary to point out to the members of this association.

MR. G. C. WHIPPLE.* The remarks of Dr. Soper lead me to say a few words in corroboration of his statement that epidemics of typhoid fever are often preceded by distinct warnings. In the paper on typhoid fever which I had the pleasure of reading before this association last winter † I mentioned the case of a town in Maine where the use of a polluted water at the time of a severe fire was followed by an epidemic of diarrhea. No attention was paid to this warning, and a few months later, when a second fire occurred, the same polluted water was again used, and this time it resulted in an epidemic of typhoid fever which gave rise to the great epidemic of typhoid fever which occurred in the Penobscot Valley.

It has been stated that typhoid fever may be due to other causes than water. It is well known, of course, that typhoid fever is found in many cities and towns where the water is absolutely above suspicion. I have recently had occasion to tabulate, for various states, the typhoid fever death-rates in certain cities and towns where the water supply was taken from driven wells. In these cases I found that the rate was, in general, quite low, much lower than in those cities and towns which used surface waters liable to pollution. It was interesting to notice that of the cities and towns which used ground water those in the northern part of the country had lower typhoid fever death-

* Consulting Engineer, New York City.

† The Kennebec Valley Typhoid Fever Epidemic of 1902–3. By George C. Whipple and Ernest C. Levy. JOURNAL, June, 1905, vol. 19, p. 147.

rates than those further south. This is shown by the following figures:

State.	Number of Cities and Towns Averaged.	Number of Years Averaged.	Average Typhoid Fever Death-rate per 100,000.
Maine	2	5	6.4
Massachusetts . . .	23	5	15.8
Connecticut	4	5	9.5
New York	13	5	24.7
New Jersey	10	1	20.5
Pennsylvania . . .	5	1	31.8
Ohio	22	5	32.4

It is a well-known fact, shown by the census bulletins, that typhoid fever is much more abundant in the South than in the North, and it is interesting to notice that these figures correspond with this fact, indicating that other causes than water supply are more operative in the South than in the North.

Mr. Bemis. May I ask Mr. Whipple what the general average death-rate was in those cities whose water was pure?

Mr. Whipple. I cannot give you exact figures, but my recollection is that in the New England States it averaged about 10 per 100 000, while in New York and New Jersey it was nearer 20. A little farther south it was still higher. The data for the southern states are very meager, perhaps at an average figure we might take 15 per 100 000.

Dr. Mason. It must be carefully borne in mind that the typhoid death-rates to which Mr. Whipple has referred show the ratio of deaths to number of people living, both well and ill. The rates to which I have asked attention indicate the ratio of severe cases of the disease to the number of people attacked, — two very different propositions.

THE MUNICIPAL WATER-SOFTENING PLANT AT OBERLIN, OHIO.

BY W. B. GERRISH, SUPERINTENDENT OBERLIN WATER WORKS.

[*Read September 14, 1905.*]

The dweller in the New England cities uses the soft water supplied without a thought that any city is furnished with any other. True, some supplies may be polluted, but when that is remedied, his anxiety ceases.

The granite hills of New England furnish a very different supply from that found in the glacial till and limestone formation of the Middle West. Many cities in this region furnish their inhabitants with a water so hard that there is a lingering doubt in one's mind whether the sticky scum left from the soap is not worse than the dirt the soap is supposed to remove. Burned-out water backs and lime-coated crockery are other inconveniences, while the steam user and laundryman are in constant trouble.

It was a common remark regarding the Oberlin water, that it was good water, if it were only not so hard.

It is a surface water from an agricultural district and shows a low bacterial content, but, like all surface water supplies, it is liable to specific contamination. The water was so hard, however, that with possibly half a dozen exceptions each family was provided with a rainwater supply in addition to the city supply.

The writer was familiar with the fact that thousands of industrial softening plants were in existence and the query arose, why not soften the municipal supply? Besides, the chemical treatment of water dates back into hoary antiquity, for nearly three thousand years ago Elisha sweetened the bitter waters of Jericho by treating with sodium chloride. (2 Kings 2: 19–22.)

The situation at our works was such that a small reservoir, constructed when the works were built, could be used as a settling basin and the water could be delivered to it without extra pumping.

While studying on the matter, we were fortunate enough to meet Mr. C. Arthur Brown, who had had considerable experience in industrial water softening, and he assured us of the practicability of the scheme. The matter was presented to the water board and they were favorably impressed.

This board, by the way, was composed of unusual men to hold such a position in public affairs. One was a professor of natural science and one was a professor of chemistry in the college, while the third was to be common pleas judge. Two of the board have died within a year, but they lived long enough to see the successful completion of the work.

Realizing that an untried field of water treatment was being entered upon, every point was carefully examined. Plans from two of the builders of industrial softening plants were sought, but both required the extra pumping of the water. Both plans were rejected for this reason and the plan submitted by Mr. Brown, which did not require extra pumping, was adopted.

The small reservoir, shown in Plate I between the storage reservoir and the pump well, and having its water level some six or seven feet lower than the water in the storage reservoir, was cleaned and paved with brick. It was also divided along its minor axis by a concrete wall, making two settling basins of 330 000 gallons capacity each, the average daily consumption being one half that amount.

In the process of treatment, the raw water, to which the chemicals have been added, passes through a mixing box, and enters the bottom of the first settling basin. It is then drawn from the top by a float arm, and the water enters the bottom of the second settling basin. It is again drawn from the top and enters the pump well. It is then pumped to the standpipe, and on its way down passes through ordinary sand pressure filters.

Taking up the various parts in detail we have:

Soda Tanks. Two soda mixing tanks, 8 feet high by 4 feet in diameter, containing mechanical agitator for mixing the soda solution, and a control tank, 2 feet high by 3 feet in diameter, which is supplied from the mixing tanks through a ball cock and then delivers the soda solution at a uniform rate.

Lime Tank. One lime tank, 14 feet high by 10 feet in diameter, containing a mechanical agitator.

Both lime and soda tanks are of Louisiana cypress and were purchased of the New York Continental Jewell Filtration Company.

Motor. The power for the agitators comes from a Pelton water motor. The water used is softened water, but not filtered, and after passing the motor enters the bottom of the lime tank and becomes the lime water for treating.

This much of the apparatus is in the rear part of the pumping station.

Mixing Box. This box is 2 by 2 feet and 40 feet long, and contains baffles. It is made of open-hearth steel. It is buried under ground with the top at the level of the water in the settling basins when full and extends from the boy to the man in the picture. It is water tight and is under a little pressure.

Behind the first baffle the lime water is admitted and behind the second baffle the soda solution enters.

Distribution Pipe. The chemically charged water from the mixing box enters the bottom of the first basin through an 8-inch galvanized wrought-iron pipe 40 feet long and containing a row of 1-inch holes 6 inches apart.

A float arm draws the clearer water from the top of this basin and it is distributed along the bottom of the second basin through a similar pipe containing ¾-inch holes.

Filters. The lower section, 40 feet, of our standpipe is of stone, as shown in Plate II, and in this are two 7 by 7-foot pressure filters.

Operation. The man who attends to the water-works grounds also attends to the treating. Every three hours he weighs out the amount of soda required for a three-hour run and charges the empty soda tank, at the same time turning on to the control tank the soda tank previously charged.

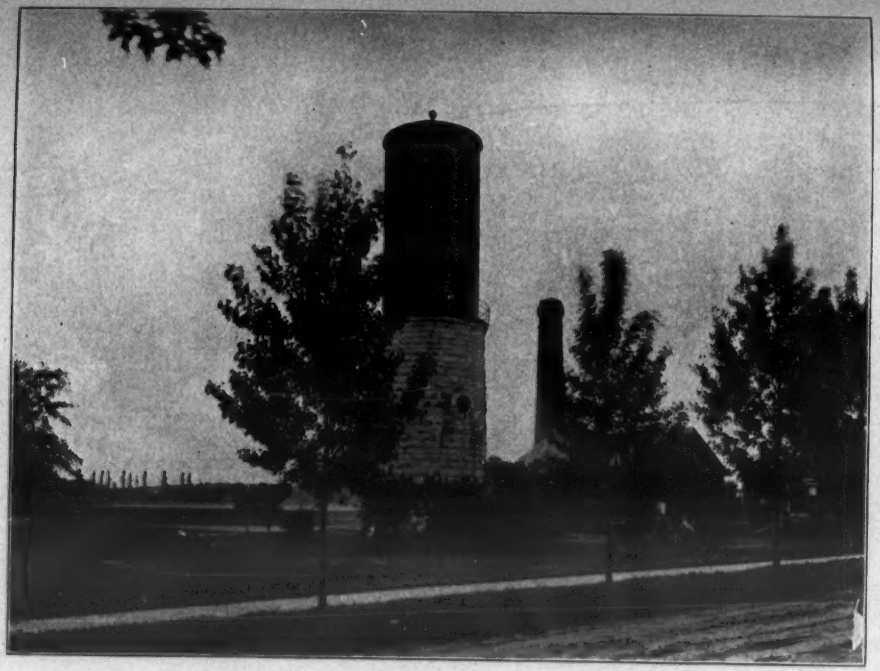
Similarly, he weighs out and slakes the amount of lime required and runs it into the lime tank. This does not give a water of exactly uniform strength, as immediately after charging the lime water is somewhat stronger than at the close of the three-hour period, but the difference is not great.

The treating is done in from six to nine hours each day.

Water. As before stated, the water is a surface water, gathered

PLATE I.

SETTLING BASIN AND STORAGE RESERVOIR, OBERLIN WATER WORKS.



STANDPIPE, OBERLIN WATER WORKS.

PLATE II.

about six miles from town and conveyed in a vitrified conduit which, in spite of careful cementing, leaks water in dry weather and admits ground water in wet weather. The soil being a glacial till, full of limestone pebbles, renders the water very hard.

The analysis of the water in summer and winter is quite different, as is shown in the following determinations:

GRAINS PER U. S. GALLON.

	April 27, 1903.	Jan. 15, 1904.	Laboratory Treatment of Second Sample.
SiO_2	.41	.79	.12
$Al_2O_3Fe_2O_3$	.09	.15	.02
$CaCO_3$	7.15	13.69	1.07
$MgCO_3$	.46	.50	1.40
$MgSO_4$	4.14	9.85	
NaCl	1.17	1.33	1.30
Na_2SO_4	.57		11.59
Organic and volatile,		2.21	.18
Alkalinity	8.16	14.30	2.70
CO_2 (free and semi-combined)	3.40	7.40	

Chemistry. The hardness of the water is caused by the rain water dissolving the " chemicals " from the soil upon which it falls. These chemicals are the carbonates and sulphates of lime and magnesium.

The process of softening depends first on the principle that carbonates are only partially soluble except in the presence of free CO_2, and second, that the sulphate of magnesium can be decomposed into insoluble calcium carbonate and magnesium hydrate, leaving a soluble sodium sulphate which does not harden the water, by adding sodium carbonate and calcium hydrate.

The reaction is as follows:

$$m(CaCO_3+CO_2)+n(CO_2)+mn(CaO)=2mn(CaCO_3).$$

$$MgCO_3+Ca(OH)_2=Mg(OH)_2+CaCO_3.$$

The sulphates react as follows:

$$CaSO_4+Na_2CO_3=Na_2SO_4+CaCO_3.$$

$$MgSO_4+Na_2CO_3+Ca(OH)_2=CaCO_3+Mg(OH)_2+Na_2SO_4.$$

And thus Epsom salt in the raw water is changed to Glauber salt in the treated water.

To the popular mind it seems to be such a paradox that we

should *add* chemicals to the water and have less chemicals in the water at the last than at the first.

However unbelieving they may be as to the theory, the results they like.

During 1904, determinations of calcium and magnesium were made at various times with the following results:

Date (1904).	Water.	Grains per U. S. Gallon.				
		$CaCO_3$.	$MgCO_3$.	$CaSO_4$.	$MgSO_4$.	Alkalinity.
June 27	Natural	10.14	.68		6.54	10.95
	Softened	2.03	1.36		.33	3.65
July 18	Natural	10.05		.73	7.53	10.05
	Softened	2.64	.38		.83	3.10
July 20	Natural	9.95		.55	7.35	9.95
	Softened	2.95		.79	.84	2.95
July 26	Natural	9.50		.43	6.96	9.50
	Softened	3.30		.26	.72	3.30
July 28	Natural	9.20		1.01	6.87	9.20
	Softened	2.16	2.13		.57	4.70
Aug. 1	Natural	10.30		.99	7.74	10.30
	Softened	2.78			.54	2.80
Aug. 4	Natural	9.45		3.15	8.10	9.45
	Softened	3.00	.50		.03	3.60
Aug. 11	Natural	9.66	.58		7.29	10.35
	Softened	2.87	.48			3.55
Aug. 16	Natural	9.82	.67		7.08	9.90
	Softened	2.00	.96			3.15
Aug. 23	Natural	10.00	.17		7.65	10.20
	Softened	2.11	.24		1.54	2.40

Since the spring of 1905, with a better knowledge of how to control the treatment, we have been able to keep the alkalinity to less than three grains per gallon most of the time, with no permanent hardness as determined by Hehner's method.

Control. The proportioning of the chemicals for such work is a matter requiring very careful attention, for there is no process of water treatment which would so soon become a byword and a hissing as the softening process if carelessly operated.

The soap determination is unsatisfactory, for it is not delicate enough even if there were no trouble from magnesium, and we find it impracticable to remove all the magnesium without leaving too high caustic alkalinity.

Neither is the control with dilute silver nitrate sufficiently delicate. In ordinary industrial work, if the water should become so alkaline as to give a brown color with silver nitrate the worst feature would be the loss of chemicals, but if the superintendent of a municipal plant should furnish such water it would mean the loss of his official head.

The water should never be allowed to give even a straw color with silver nitrate. But from a straw color through a very slight cloudiness to white is a long range.

The most satisfactory control for our particular water is to titrate the treated water taken from the center of the distribution system with $N50H_2SO_4$, using phenolphthalein first as an indicator and then methyl orange, and the ideal treatment gives the following results, using 58.38 cc. of the water, or a miniature United States gallon.

1.8+0.8=2.6 total alkalinity, provided the soda treatment is adjusted to give no permanent hardness.

If the results are

(1.8—)+(0.8+), then too little lime is used.

(1.8+)+(0.8—), then too much lime is used.

The above is entirely empirical.

At the same time that the lime is being adjusted, the soda is controlled by Hehner's method as follows:

Take 58.38 cc. of the water and add $N50Na_2CO_3$ in excess. Evaporate to dryness. Wash with boiling water and filter. When cold, titrate as before, using methyl orange as an indicator.

If the amount titrated back is less than the alkali added, the difference indicates the amount used in precipitating the calcium and magnesium, which produced permanent hardness. If the amount titrated back is greater than the amount of alkali added, then it indicates that the water contains alkali carbonates which have been reckoned as alkalinity, or in other words, too much soda has been added.

Lime. The Ohio limes are high in magnesium and contain only 50 per cent. of CaO, so that they are not adapted to this use. We get a lime from the Mississippi River containing about 90 per cent. CaO, and by buying it in bulk, get it at the same price as the Ohio lime in barrels.

Soda. In the purchase of soda there is little choice.

The maximum amount of lime used the past year was 17 grains per gallon of water and the minimum was 6 grains, while the maximum of soda was 6 grains and the minimum was 2 grains per gallon.

Bacteriology. While we had a water supply that had never been suspected of causing a case of sickness, still it was liable to specific contamination. It was the desire of the board to provide, if possible, against such a possibility.

When a coagulant like alum or lime and copperas is used it is the idea that the precipitate formed will entangle the bacteria and carry them down. It will at once be seen that if the small precipitate formed by these chemicals will be so effective, how much more effective must be the heavy precipitate formed by the lime and soda ash.

By the accompanying table it will be seen that 90 per cent. of the bacteria are removed in the first basin, while the water delivered to the village contains less than 5 bacteria per cubic centimeter — a result not attained elsewhere to my knowledge.

REPORT OF G. R. PATTON OF BACTERIA FOUND PER CUBIC CENTIMETER.

Date (1904).	Storage Reservoir.	First Basin.	Second Basin.	Hydrant Water.	Hydrant Water.	Colon Bacilli. Storage Res'voir.	Colon Bacilli. Hydrant Water.
Nov. 28	440	50	10	4	6		
„ 29	800	60	30	6	0		
„ 30	300	50	37	12	6		
Dec. 1	320	50	20	16	17		
„ 2	160	30	20	4	7	Yes	No
„ 5	300	25	12	6	5		
„ 6	350	12	2	4	2	Yes	No
„ 7	Error	45	7	1	2		
„ 8	300	156	6	1	3		
„ 9	300	11	11	5	5	Yes	No
„ 12	Lost	20	5	1	4		
„ 13	250	20	10	6	6	Yes	No
„ 14	500	12	10	1	0	Yes	No
„ 15	400	10	7	1	4		
„ 16	400	10	4	0	2		
Average,	370.76	37.40	12.73	4.53	4.60		
Per cent. reduction,		89.91	96.56	98.78	98.75		
Found by E. G. Horton, of State Board:							
Aug. 18	492		33			Yes	No

In the spring the bacterial content of the raw water rises to several thousand per cubic centimeter, but the filtered water shows almost as good results as in the above table.

Troubles. But does not the water taste badly? Well, if there was ever a case where the popular imagination ran riot it was in the chemical treatment of water. When the treatment began, there was hardly an imaginable taste not detected, and sickness of every description was attributed to it. Time has wrought wonders in the public palate, which has now become accustomed to the absence of the chemical substances formerly in the water. There is still an occasional rumble from the first storm, but the general opinion is one of high appreciation. Rain water supplies are being rapidly abandoned, and there is a decided increase in our receipts — in fact, an increase much more than the increase in the cost of the operating expenses.

The holes in the distribution pipe in the bottom of the first basin become filled with a hard formation of lime which needs to be poked out every week. In six weeks the holes will become entirely filled.

The holes in the distribution pipe in the second basin will be filled in as many months.

This tendency of the treated water to form deposits, especially where there is a constriction and consequent rapid flow, is the one thing about the process to cause anxiety. Our treatment was started December 28, 1903, and has been continuous ever since except the month of March, 1904, when some uncompleted work was finished. In October, 1904, the mixing box was opened and there was a soft deposit on the sides from $\frac{1}{4}$ to 1 inch in thickness, and in contact with the steel a very hard deposit about $\frac{1}{16}$ inch thick. Whether this hard deposit will increase or whether the soft deposit will wash off with the flow, time will tell.* The distribution pipe in the first basin and the vitrified pipe connecting it with the mixing box have been cleaned several times of an inch or more of a hard deposit. The sides of the basin, whether of stone, brick, or concrete, show no incrustation, while the float

*On September 21, 1905, the mixing box was again opened. Sufficient deposit of lime was found at the ends of the baffles and at the outlet to nearly cut off the flow. We may therefore, expect to clean the mixing box once a year.

and float arm of galvanized iron show a hard deposit an eighth of an inch thick. Closing the gate between the two basins requires considerable work. There is very little trouble in the second basin. After over a year's use the pump cylinders were opened and we found them beautifully white, but no appreciable deposit.

The precipitate in the first basin amounts to about a foot a month, while in the second basin only about 4 inches accumulated in twenty months. This precipitate is emptied in a creek by gravity.

Upon the sand of the filter there forms a coating of the carbonate of calcium and magnesium, so that after fourteen months' use the effective size changed from .37 mm. to .55 mm. and the uniformity coefficient from 1.62 to 2.0. This makes $\frac{7}{8}$ of the bulk carbonate and $\frac{1}{8}$ sand. The bulk of the sand of the filters has been increased so that is was impossible to operate the rakes, and a foot of sand has been removed from the filters. In time the sand will have to be cleaned or new sand put in.

The filters are washed twice each week by reversing the current and stirring with rakes operated by hand power. Often there is no loss of head before washing, but sometimes there is a loss of two feet. When dirty it takes four minutes to wash a filter, and requires about 2 000 gallons of water.

There is no " after precipitation " noticed except in two cases where the water is warm and allowed to stand in that condition for a long time.

A careful watch is being kept on the meters to see if a deposit of the carbonate of lime forms on the inside. In no case thus far has the writer been satisfied that any harm has been done. If there should be trouble it could be easily remedied by putting enough CO_2 into the water to fix the carbonates, as is usually done where lime only is used for softening.

A curious phenomenon has been noticed in the hardness of the raw water in the spring. After the first decidedly warm days came in April, when no water was being admitted to the storage reservoir, in four days the water changed in alkalinity in the ratio of 31 to 18, and a few days afterward the permanent hardness changed as much and as suddenly. The semi-annual " overturn " is the only explanation we can offer.

Remarks. There seems to be quite a disposition on the part

of manufacturers of softening machines to show how quickly the water passes through and how little tankage is required. The writer's observation has led him to the conclusion that, for our water at least, the softening process is one requiring considerable time. As before noted, each settling basin contains twice the amount of a day's consumption, but at the time the following samples were taken (August 23, 1905) the consumption was only one third of the capacity of each basin.

	Grains per U. S. Gallons.		
Sample.	Alkalinity with Phenol.	Alkalinity with Methyl Orange.	Total Alkalinity.
Raw water			12.0
Basin No. 1	3.3	3.2	6.5
Basin No. 2	3.0	2.1	5.1
Past filters	1.9	0.8	2.7
Center of system . .	1.7	0.8	2.5

This series of determinations shows the improvement of the water by standing and also the effective work of the filters.

When we are using more water there is always an improvement of .5 or .6 grain of alkalinity per gallon between the water as it passes the filters and the center of the distribution system, instead of only .2 as here shown. We should therefore conclude that to reach the best results there should be about six days of sedimentation before filtering.

The action of the soda seems to take place entirely in the first basin, as a sample from there shows the same results when tested for permanent hardness as one taken from the center of the distribution system.

The query which rises in the mind of every water-works manager is, Does not the process cost too much to be practicable? In a system that requires you to pour four gallons into the bung to draw one at the spigot there is no question that it would be financially ruinous, but in a system that can account for one half or more of the water pumped it certainly is practicable. For water such as ours the chemicals cost one cent per thousand gallons delivered, while labor, interest, and depreciation will probably add a cent and a half more, making the cost of softening the water delivered to the pumps 2½ cents per thousand gallons.

The cost can be but very little reduced from this, no matter how much water is treated.

If half of this is delivered through the meters it would add to the present cost in any such system five cents per thousand gallons — a sum which any community can afford to pay for water of such a quality. In our own system, by shutting off the sewer flush tanks and horse troughs, the use and consumption between 10 P.M. and 4 A.M. is only 500 gallons per hour, with 10 miles of mains and 900 taps, but we are not able to account for as high a percentage of the total amount pumped as we would like. Every water-closet in town is metered, even in schoolhouses and other institutions having free water. The result is that 80 per cent. of all taps in use are metered.

To a town which is obliged to purify its sewage there is an additional advantage in the use of the softening process. As has been noted, the water is in general alkaline to phenol to the extent of about 2 grains per gallon. For precipitation with copperas it is necessary to have the water alkaline. During two summers now we have used copperas for precipitating the sewage and have gotten very satisfactory results. The sewage farm has been entirely free from odors and the effluent which enters what is practically a dry run causes no nuisance. It was found, however, that the water in changing to sewage absorbed enough CO_2 to become neutral and it is necessary to add some lime.

The use of the softened water has been entirely satisfactory in house aquariums and the goldfish have done well in it, as is not the case sometimes when other coagulants are used. In blowing dead ends it is found that there is no odor to the water.

The possibilities of the lime-soda process for municipal use seem to be little appreciated as yet, but the time will doubtless come when it will be the means of solving some of the vexing problems of water supply in the middle West.

DISCUSSION.

MR. KENNETH ALLEN. I should like to ask what the capacity of the plant is and what it costs.

MR. GERRISH. Our consumption averages 165 000 gallons, and the cost was about $12 000.

DR. FREDERICK S. HOLLIS.* I think we are especially indebted to Mr. Gerrish for the description which he has given us of the water-softening plant at Oberlin. We who live in New England can have little conception of the inconvenience of having a supply of water as hard as that of some of the towns of the middle West. Our trans-continental lines have been foremost, perhaps, in erecting softening plants for the purpose of preventing scale from forming in their boilers, and many of our industrial plants, especially where dyeing is carried on, are obliged to soften the water which they use because the lime salts will in many cases give a different color with the dye from that which is desired, and sometimes they will change the texture of the fabric somewhat; but I do not recall any other such plants in connection with domestic supplies.

The inconvenience of having a domestic supply so hard as it is in some of the western states is largely because of the power of such water to combine with soap. The expense of softening the water per 1 000 gallons has been given, and I should think that would probably be more than saved to the community in the saving in soap necessary for washing and domestic use. Then another thing I have noticed, especially in Ohio, where I first had experience of this kind, was that in order to soften this water for domestic use, with as little soap as possible, a soap that was extremely strong, that is rich in alkali, was used. I well remember what disastrous effect such soap had on the skin, and I can imagine what its continuous use must be on the fabric of clothing.

In New England the water in most of our city supplies is only moderately hard. In the Connecticut valley, — and by the Connecticut valley I mean the line of the old Jura-Trias valley bounded by the sandstone formation, — some of the ground water is extremely hard, but most of our supplies are not of the nature described by Mr. Gerrish, and we do not realize the importance of the problem until we go outside of New England.

MR. G. C. WHIPPLE.† I am extremely glad that Mr. Gerrish has presented this paper, for the plant at Oberlin was the first municipal water-softening plant erected in the United States,

* New Haven, Conn.
† Consulting Engineer, New York City.

although the one at Winnipeg, Canada, antedates it. We are certainly very fortunate in having such a complete description from the superintendent.

There is one point that Mr. Gerrish mentioned which interested me considerably, namely, the time element which enters into the chemical reactions involved in the softening of water. Mr. Gerrish rightly says that these reactions do not take place instantaneously, but require a certain amount of time. It is due to the slowness of these reactions that " after deposits " of calcium carbonate occur in the pipes and filters. These " after deposits " are often very troublesome. You will recall that when lime is added to water it acts on the calcium bicarbonate, changing it to calcium carbonate, and on the magnesium bicarbonate, changing it to magnesium hydroxide. Experiments which I have made recently have shown that the magnesium reaction takes place very much more rapidly than that of calcium, and it is for this reason that most of the " after deposits " are composed almost entirely of calcium carbonate and contain almost no magnesia. While it is true that most of the precipitate settles in about six hours, it takes several days for the final reaction to be complete. An examination of several plants which differ considerably in the time allowed for the chemical reaction shows that practice follows theory in this matter. Those plants providing for only a few hours' sedimentation do not give as good efficiencies as those where greater time is allowed. In the plant at Oberlin the final alkalinity is often as low as 30 parts per million. At Winnipeg, where the time for chemical reaction is less than two hours, the resulting alkalinity is about 80 parts per million. Other plants, intermediate between these two, give intermediate results.

The " after deposits " which take place on the sand grains of the filter and in the distribution pipes may be prevented by what is called " recarbonation," that is, the artificial addition of carbonic acid. This unites with the normal calcium carbonate and the magnesium hydroxide and causes them to be changed to bicarbonates which are soluble. In industrial water-softening plants recarbonation is seldom practiced, but if municipal water-softening plants are to develop, as seems likely, this matter must receive very careful attention.

MR. ROBERT S. WESTON.* Such papers as this excellent one by Mr. Gerrish are most timely. Very little has been said in this country concerning the softening of municipal water supplies. There are many cities in the country in which there is such a waste of soap that if opportunity could be given in those cities for the writing of such a descriptive paper as this, a great step in municipal economy would have been taken.

Referring to the point which Mr. Whipple has spoken of, namely, the period of sedimentation thought necessary to produce satisfactory results, one naturally asks if the same effect could not be produced by active mixing or stirring, or by some other similar procedure. It might be cheaper to do the work in this way than by a long period of storage in subsiding basins, where mixing must be by diffusion, although it must be recognized that even under the most favorable conditions the action between the added chemicals and the salts in the water is not an instantaneous one, but one requiring considerable time.

The speaker would like to ask Mr. Gerrish if the precipitation in the plant at Oberlin is so complete as to prevent practically the after-precipitation of lime salts in the underdrains of the filters. This is mentioned because a similar difficulty has been met with in Europe in a good many cases, probably because the process has been hastened unduly by not providing such ample storage as has been arranged at Oberlin. In these cases the water is not adequately treated; the filters become incrusted with salts of lime, clog, and are condemned; whereas, were ample provision made for removal of the precipitate the plants would probably be entirely successful. The speaker remembers, for example, that at Canterbury, England, where less than six hours' treatment is provided for, the after-precipitation of lime frequently causes annoyance, especially at times of unusual draft upon the supply.

MR. GERRISH. I will say that this matter of how much time would be required did not come to my notice until the month of August. A great many of our people move out of town during that month, and our consumption is very light then, so we had an opportunity to give the water about six days of precipitation,

* Sanitary Expert, Boston, Mass.

and by that means, as I said, I very seldom got any decrease in alkalinity between the filters and the taps in the middle of the city, whereas previous to that I always got a difference of .5 or .6 of a grain. From that I concluded that six days in the case of our water would be the maximum time required for complete precipitation. If we could give the water six days' precipitation all the time, I don't believe we would have any trouble with the filter, for then there would be no change in the water after it left the filter.

I would say, in regard to plants of this kind, that the plant at Winnipeg uses lime only; there is a plant at Freeport, Ill., for taking out iron, which uses lime only. So far as I can find out, the Oberlin plant is the first plant, either in this country or abroad, for a municipal supply using lime and soda.

MR. WESTON. I should like to ask Mr. Gerrish one more question. Has there been any great decrease in the amount of soap used in the town? Have the grocers commented on it, for example?

MR. GERRISH. I went into one grocery store and made that inquiry, and they seemed so entirely at sea as to what I meant when I asked the question that I really lost heart about getting any data of that kind. I may say that in my own family I have noticed a very decided improvement in that regard.

SOME FEATURES OF ESTIMATING STREAM FLOW IN NEW ENGLAND.

BY H. K. BARROWS, DISTRICT HYDROGRAPHER, UNITED STATES GEOLOGICAL SURVEY, BOSTON, MASS.

[*Read September 15, 1905.*]

The object of this paper is to discuss some of the features of estimating river flow in the New England states as now being carried on by the Hydrographic Branch of the United States Geological Survey, and, in general, to better acquaint the members of this association with the nature of the work that is being done by this bureau of governmental service.

The United States Geological Survey has been in existence since 1879, as one of the branches of the Department of the Interior. Its work has covered a broader field than that of geology ever since the beginning, and in some respects its name is therefore misleading. The Geological Survey has five subdivisions, as shown by the following table:

Administrative.	Executive.
	Disbursements and accounts.
	Library.
Geologic.	Geology.
	Alaskan mineral resources.
	Mining and mineral resources.
	Chemical and physical researches.
Topographic.	Topography.
	Geography and forestry.
Hydrographic.	Hydrography. Districts: (1) New England, (2) New York and Great Lakes, (3) Middle Atlantic States, (4) Southern States, (5) Central States, (6) Texas, (7) Western States with numerous subdivisions.
	Hydrology.
	Hydro-economics.
	Reclamation service.
Publication.	Editorial.
	Engraving and printing.
	Documents.

Perhaps the one which has been best known to engineers in the past is the Topographic Branch, which will eventually complete a topographic map of the United States. This work is proceeding slowly, and, at the present time, perhaps about one third of the whole country is thus mapped. The Hydrographic Branch has been a distinct feature of the Survey since 1888, and now consists of several subdivisions, as shown, at the present time it being one of the most important divisions of the Survey.

It is interesting to note the growth of the Geological Survey as shown by appropriations. Thus, the first appropriation in 1879 was $106 000; while for the last fiscal year something over a million and a half dollars were appropriated — the larger items being as shown in the following list:

Topography	$300 000
Geology	150 000
Alaska	60 000
Hydrography	200 000
Chemical and physical researches	20 000
Mineral resources	50 000
Engraving and printing maps	100 000
Surveying forest reserves	130 000

The chief work of the Hydrographic Branch has been that of estimating river flow, and, in general, investigating the water supply of the country. For many years all of the work of this branch was carried on in the West and only recently were begun the systematic measurements of river flow east of the Mississippi River.

The first work of this kind in New England dates back to 1900, when a gaging station was established upon the Connecticut River at Orford, N. H., this being still in operation at the present time. At about the same time another station was established on the Housatonic River at Gaylordsville, Conn. These stations were established with the idea of getting some general information on the subject of river flow in this vicinity. The first systematic measurements on a considerable scale began in 1901 in the state of Maine, and were made possible through the coöperation of private parties. This was in the Kennebec River valley, where a number of the water-power users and lumbermen desired to ob-

tain some reliable figures of flow of the river and its tributaries, and, in general, such information as would be of use in developing and maintaining water powers. This work was done by the United States Geological Survey in coöperation with these private parties, and, as government funds became available, in the course of the next year measurements were started on some of the other important rivers of the state. The state, too, at the next session of the legislature, recognized the value of the work by making an annual appropriation for hydrography, which has been continued up to the present time, and largely increased during the past year. In 1903 the United States appropriation became sufficient to permit of this stream work being extended to the other New England states, and this was first done in the states of New Hampshire and Vermont. About this time New Hampshire became interested in the hydrography of the White Mountain region in connection with the investigations of the State Forestry Commission, and a state appropriation was made, and coöperative work begun with the Geological Survey in a study of river flow in the White Mountains, particularly with regard to the effect of deforestation upon run-off. This work is still going on, and it is hoped that some definite results will, in time, be obtained, although, of course, such a problem is not one capable of an immediate solution. In the lower New England states the work of stream measurement dates back to the spring of 1904. The present location of stations maintained by the Geological Survey is shown in the following table:

MAINE.

	Date Established.
Fish River at Wallagrass	July 29, 1903
Aroostook River at Fort Fairfield	July 31, 1903
St. Croix River at Sprague's Falls, Baring	Dec. 4, 1902
Machias River at Whitneyville	Oct. 17, 1903
Penobscot River at West Enfield	Nov. 5, 1901
East Branch, Penobscot River, at Grindstone	Oct. 23, 1902
Mattawamkeag River at Mattawamkeag	Aug. 26, 1902
Piscataquis River at Foxcroft	Aug. 17, 1902
Cold Stream at Enfield	June 14, 1904
Phillips Lake Outlet, Holden	July 7, 1904
Phillips Lake Outlet, Dedham	July 19, 1904
Kennebec River at The Forks	Sept. 28, 1901

	Date Established.
Kennebec River at North Anson	Oct. 18, 1901
Moose River near Rockwood	Sept. 7, 1902
Roach River at Roach River	Nov. 10, 1901
Dead River near The Forks	Sept. 29, 1901
Carrabassett River at North Anson	Oct. 19, 1901
Sandy River near Madison	Mar. 23, 1904
Messalonskee River at Waterville	June 18, 1903
Androscoggin River at Dixfield	Aug. 22, 1902
NEW HAMPSHIRE.	
Androscoggin River at Shelburne	May 30, 1903
Saco River at Center Conway	Aug. 26, 1903
Merrimac River at Franklin Junction	July 8, 1903
Pemigewasset River at Plymouth	Sept. 5, 1903
Contoocook River at West Hopkinton	July 9, 1903
Connecticut River at Orford	Aug. 6, 1900
Israel River (above South Branch), Jefferson Highlands	Sept. 2, 1903
Israel River (below South Branch), Jefferson Highlands	Sept. 2, 1903
Ammonoosuc River at Bretton Woods	Aug. 28, 1903
Zealand River at Twin Mountain	Aug. 29, 1903
VERMONT.	
Otter Creek at Middlebury	Apr. 1, 1903
Winooski River at Richmond	June 25, 1903
MASSACHUSETTS.	
Connecticut River at Sunderland	Mar. 30, 1904
Deerfield River at Deerfield	Mar. 30, 1904
Ware River at Ware	Sept. 15, 1904
Quaboag River at West Warren	Oct. 25, 1904
Westfield River at Russell	Apr. 1, 1904
Westfield Little River at Blandford	July 13, 1904
RHODE ISLAND.	
Blackstone River at Woonsocket	Apr. 5, 1904
CONNECTICUT.	
Shetucket River at Willimantic	Apr. 4, 1904
Salmon River at Leesville	Mar. 16, 1905

Another object of the Hydrographic Branch is to publish estimates of stream flow made by private parties, where such can be

obtained of reliable character, and a considerable amount of information is placed on record in this way in the Annual Progress Reports of the Survey. At present, records of flow by private parties are obtained and published for the following points:

MAINE.

Penobscot River at Millinocket.
Kennebec River at Waterville.
Cobbosseecontee River at Gardiner.
Androscoggin River at Rumford Falls.
Presumpscot River at Sebago Lake.

NEW HAMPSHIRE.

Androscoggin River at Errol Dam.
Androscoggin River at Gorham.
Merrimac River at Garvins Falls.

MASSACHUSETTS.

Sudbury River at Framingham.
Merrimac River at Lawrence.
Lake Cochituate at Cochituate.
Nashua River at Clinton.
Ware River at Gilbertville.
Swift River at West Ware.

CONNECTICUT.

Connecticut River at Hartford.

Since 1903, a permanent force of hydrographers has been maintained for work in the New England District, and a branch office of the Survey is now located at Boston.

METHODS IN USE FOR ESTIMATING FLOW.

It is not the purpose of this paper to enter into details of the methods used, for these are explained very fully in the various Water Supply Papers that have been published. A brief outline, however, will perhaps be desirable. The principal method is that of estimating discharge by means of daily gage heights, and a discharge rating curve, based upon current meter measurements of flow at different stages, such that the discharge may be ascertained for any given gage height. There is required, then, a gage

suitably established, either of a permanent character or such that it can always be replaced according to the same datum, and some one to read this gage a sufficient number of times a day (usually twice), to give the mean height for the day. The gage most in use at the present time is what is known as the "Standard Chain Gage," which is capable of adjustment and frequently tested. The observer is some one living near by, perhaps a farmer, postmaster, or station agent.

To get a rating curve for the station, current meter discharge measurements are made by the hydrographer at different gage heights — any one measurement giving by means of soundings the area and by current meter observations the mean velocity — the product of these two factors being the discharge for a given gage height.

The current meter in most general use, and which has proven most satisfactory for river conditions, is the Price electric current meter.

The above method assumes that the discharge is always the same for a given gage height — condition of bed, banks, etc., of course, remaining the same. This is not strictly true, as the effect of slope of water surface is neglected, but, under the usual condition of rate of rise and fall, however, no great error is involved.

The other general method now used for estimating stream flow consists in utilizing water-power plants for the purpose. Thus, in many cases, it is practicable to use a dam as a weir, supplementing this, if necessary, by a record of gate openings and head on the wheels, and thus procuring data to compute the daily discharge.

LOCATING CURRENT METER STATIONS.

Perhaps the most important essential in locating a current meter station is that of obtaining what may be called a true or undisturbed gravity flow. It is not always easy to find this condition, and, in fact, upon some of the New England rivers it is well nigh impossible to find any great length of river that is not liable to effect from artificial causes. It is very evident that if back-water effect occurs from any reason, the usual relation between the gage height and discharge is at once changed. There are a variety of causes for this, the most common one being a dam downstream from the

FIG. 1. U. S. GEOLOGICAL GAGING STATION AT WEST WARREN, MASS., ON THE QUABOAG RIVER.

FIG. 2. MAKING CURRENT METER MEASUREMENTS THROUGH THE ICE AT RICHMOND, VT., ON WINOOSKI RIVER.

gage and near enough to give this effect. Another source of back-water effect which often prevails is that of a stream entering the main river somewhat below the point under consideration, but of sufficient size and difference in distribution of run-off to change the conditions of flow in the vicinity of the station. Lakes or ponds, where considerable fluctuations of level exist at various times of the year, must, of course, be sufficiently distant from the gage to give no back-water effect. The matter of horizontal distance is not always the important thing in the above; for frequently back-water influence exists for many miles. Thus, as an illustration, on Otter Creek, the dam at Middlebury, Vt., probably affects the water level for a distance of twenty miles or more, while there are many cases where the influence of a dam is felt but a few hundred feet upstream. Back-water effect may also be caused temporarily by ice or log jams, and, of course, while such conditions prevail it is difficult or impossible to obtain good estimates of flow.

CHANNEL CONDITIONS.

The ideal in this respect would be a portion of a river with a permanent and smooth bed and with a straight channel both above and below the point considered, so that an even and regular flow could be obtained at all stages, and with a good velocity at low water, and not too swift for high-water conditions; moreover, the banks should be high enough not to overflow during floods. The above requisites are never met with completely, and it is usually a question of waiving some one or more of these desirable features and doing the best possible under the circumstances. In general, permanent conditions of the stream in the vicinity of the gage, although the bed be rough, are better than a smoother channel which, however, shifts or scours at times. The purpose for which the measurements are made usually has considerable weight in the selection of the station. Perhaps the most common way in which stream measurements are useful here in New England is in connection with water powers, and for such purposes it is the estimates of low water which are the most valuable. Consequently, under these conditions, the hydrographic features at low-water stages would have the most weight.

KINDS OF STATIONS.

A *bridge* is used whenever channel conditions are at all suitable in the vicinity, and these vary in convenience from the modern steel highway bridge, open and easy to work from, to the old covered wooden bridges, many of which still exist and which are often very difficult to utilize. Some of these latter have a narrow open space at the top, or a sufficient opening between flooring and bottom chord to permit of passing the current meter through, while in a few cases it is necessary to tear up a line of floor planks every time a measurement is made. The standard chain gage is best adapted for use at a bridge station, although frequently a staff gage can be readily placed on an abutment or pier. Railroad bridges of the deck type are often found which would make good stations as far as hydrographic conditions go, but cannot be considered on account of the danger involved in using them.

A *cable* with a suspended car is frequently a necessity where no bridges are available. In this case it is some times possible to fasten a chain gage to trees on the bank, or a staff gage to a bowlder. As the site for a cable station can be picked with the best conditions in mind, the results at such stations are usually of the best. The first cost of such a station is, of course, considerable, and, moreover, the cable and anchorages have to be carefully looked after and kept in repair to insure safety to the hydrographer.

A *boat* or *canoe* is frequently used in making current meter measurements. Under good conditions — no wind and not too swift a current — fairly good results can thus be obtained by the use of stay lines at both bow and stern. It is, perhaps, the most unsatisfactory method, although sometimes necessary where the expense of a cable would be too great.

Measurements are frequently made by *wading* and with excellent results. Very often a gaging station which would otherwise be useless at low water, owing to sluggish current, can be operated by finding some site nearby where good velocity conditions exist.

OPERATION OF STATIONS.

It is the practice to check up gages at least once a year with a level, and in some cases still more often. This is done by the

FIG. 1. WESTFIELD LITTLE RIVER, NEAR BLANDFORD, MASS.
GAGE USED WITH CABLE STATION.

FIG. 2. WESTFIELD LITTLE RIVER, NEAR BLANDFORD, MASS.
CLEARING UP CHANNEL WITH DYNAMITE.

use of permanent bench marks on shore referred to the gage datum. Whenever it is practicable some point on bridge or bank over the water is selected by levels also referred to gage datum, and, by measurement to the water surface with steel tape, used in checking gage readings. Where chain gages are used the chain is very frequently measured and correction made if necessary.

An old covered wooden bridge has been known to settle as much as 0.2 foot in six months, while frequently on modern structures no appreciable settlement occurs for years. The gaging station on Zealand River, near Twin Mountain, N. H., has required frequent attention, the gage being fastened to two trees on the bank, one of which occasionally settles, so that a total vertical change of 0.27 foot has occurred in the position of the gage since its installation about two years ago.

There are various causes which may at times prevent a good current meter measurement. Thus, if there is a rapid fluctuation in gage height during the measurement, poor results will be obtained, and where gagings are desired under such conditions, rapid methods must be used. For instance, velocity observations may be taken at one foot depth, and the soundings left until afterward. By taking a few vertical velocity curves just after the gaging is completed, the coefficient to apply to the observations at one foot depth may be determined.

Rapid fluctuations in height occur upon some of the Maine rivers owing to the use of stored water for driving logs, and while this is being done — from perhaps May to August — considerable care has to be taken in reading and interpreting gage heights, and quick methods used for gagings. Thus, on the Kennebec River at The Forks during the week of July 16–23, 1905, the average morning reading was 1.71, corresponding to a discharge of 1 125 cubic feet per second; while that at night was 5.59, which corresponds to about 8 775 second-feet. This is due solely to differences in gate openings at Moosehead Lake, some twenty-five miles away, and gives some idea of the amount of water being used for log driving.

Temporary obstructions, as log or ice jams below the gage, or an accumulation of logs at the gage, may absolutely prevent gaging. The Androscoggin, Kennebec, Penobscot, and St. Croix rivers and

their tributaries are especially apt to give trouble in this way during the log-driving season. Current meter measurements frequently have to be made while logs are running, but great care and watchfulness are required to do this without injury to the meter.

Anchor ice may, under certain conditions, form in the late fall and early winter before the rivers are completely frozen over, and make sufficient obstruction to affect gage readings. Thus, upon the Westfield River at Russell, Mass., on November 29, 1904, when the river bed was more or less coated with anchor ice, at gage height 0.99 a current meter measurement gave a discharge of 196 second-feet. The estimated discharge from the rating curve at this gage height is 250 second-feet, and the percentage error of this measurement of some 28 per cent. is probably mostly due to this cause. It will perhaps be of interest in this connection to note that a current meter measurement at low or medium gage height is rejected entirely if varying more than 5 per cent. from the curve.

The general practice when under high-water conditions, the current being so swift as to prevent holding the meter at any great depth below the surface, is to make observations at one foot depth (which can usually be done), and apply a coefficient obtained by study of vertical curves for the station at lower gage heights. The distance of the bridge above the water surface is a very important factor in holding the meter.

ESTIMATES OF FLOW DURING THE WINTER SEASON.

For a considerable portion of the year in New England the rivers are frozen over, and while in this condition at a given station the relation between gage height and discharge, which exists under open-water conditions, no longer prevails. The ice cover forms usually during the period from the middle of November to the first of January, depending upon latitude and conditions; while the ice remains in many streams as late as the first of April and some times up to the first of May. There is, consequently, a considerable portion of the year when different methods of estimate must be used from the ordinary. In winter, too, the measurement of precipitation is more difficult and available data less accurate than for the summer season. In fact, there

FIG. 1. AROOSTOOK RIVER AT FORT FAIRFIELD, ME. GAGING STATION — INTERFERENCE WITH LOGS.

FIG. 2. MOOSE RIVER AT ROCKWOOD, ME. CABLE STATION.

is not even an approximate relation between snowfall and stream flow, so that no estimate of stream flow can be made from the precipitation in winter. In the northern New England states especially, the minimum flow for the year may occur during the winter season, as the inflow of the streams is generally from springs, ground water, and lake storage. A water-power plant is often taxed at its highest capacity during the winter time, as the days are much shorter and more power is consumed in lighting. Consequently, it is often of the utmost importance to know something definite of winter flow under such conditions. There are numerous difficulties met with in making winter estimates of flow by any of the ordinary methods, and for this reason the data relative to winter flow of streams are very meager compared with those for the rest of the year.

CURRENT METER STATIONS IN WINTER.

The condition of New England streams during the winter season may perhaps be classified as follows:

(1.) Streams which do not freeze over, or perhaps only for short times. This may be due to several causes. The most common case is that of a stream near the outlet of a lake and where the velocity is considerable. Frequently a river will be open for some little distance below a dam, if quick water exists.

(2.) Streams which freeze over smoothly and permanently for the winter, and where the range of rise and fall is small.

(3.) Streams where ice conditions change frequently, due to breaking up of ice or the formation of anchor or needle ice.

Estimates of flow for the first two classes are usually practicable, although the cost may be two or three times that for the open season.

METHODS USED.

During the winter of 1903–4, out of thirty current meter stations maintained in New England, a record of gage heights to water surface in a hole cut in the ice, and the data relating to the thickness of the ice, was kept at sixteen, and at one station some current meter measurements of flow under the ice were made. During the winter of 1904–5, data regarding gage heights, etc., were obtained at twenty-seven out of forty current meter stations, and

current meter measurements made at three stations. The effort has been to procure sufficient data as regards gage heights, etc., to be able to compute the flow during these winter months later on when perhaps meter measurements will have been made in sufficient number under ice conditions for a winter rating curve, or perhaps a relation established between summer and winter flow for a given station. This feature of estimating stream flow must be regarded as largely experimental up to the present time.

The manner of using the current meter under winter conditions has been to cut holes in the ice, perhaps two feet long and one foot wide, at intervals of 10 or 20 feet or less, depending on the total width of the river. Velocity observations have been practically all made by the multiple point method, and vertical velocity curves obtained, as it is desired to procure as much information as possible on the form of velocity curves under ice conditions, and to furnish means for study to determine other methods which will be quicker as regards field work. The current meter has to be kept in the water continuously or it will become coated with ice and impossible to use. In some cases it has been found that considerable pulsations occur of the water through holes in the ice. At Richmond, Vt., on Winooski River, holes being five feet apart, rapid pulsations of a half foot or less occurred and caused considerable trouble at first. This was stopped by cutting between a few of the holes and making a continuous channel.

USE OF WATER-POWER PLANTS FOR ESTIMATES IN WINTER.

The difficulties under such conditions are that the dam frequently becomes coated with ice and so changed in the cross section and in conditions as to make the flow over it very difficult to ascertain. Where the flow is largely through the turbines, less trouble occurs, and fairly good estimates of flow may be obtained in this way.

OTHER WORK OF THE HYDROGRAPHIC BRANCH IN NEW ENGLAND.

This branch of the Geological Survey is not limited to the estimation of stream flow, but is intended to cover the broad subject of hydrography, and, in general, to aid in the study and solution

FIG. 1. MOOSE RIVER AT ROCKWOOD, ME. GAGE USED WITH CABLE STATION.

FIG. 2. EVAPORATION PAN AND FLOATS IN ANDROSCOGGIN RIVER, AT LEWISTON, ME.

of problems connected with river flow and with the lakes of New England. Thus, in the state of Maine, surveys of some of the important water-power streams have been made for the purpose of obtaining plans and profiles. In 1904, the Kennebec and Penobscot rivers were covered in this way for a considerable part of their length. During the present season the survey of the Androscoggin River has been begun, and further work done upon the Kennebec and Penobscot rivers.

Another feature of Maine hydrography that is now being studied by the aid of surveys is that of storage in the Kennebec River headwaters. This stream is naturally endowed with a great series of lakes which are admirably suited for storage purposes, the largest of these being Moosehead Lake. While some regulation has been made of the outflow of these lakes, there still remains considerable to be done before the minimum flow of the Kennebec River is brought to the desirable pitch.

The study of evaporation is being carried on, and during the present summer stations to measure this and to procure the attendant meteorological data are being maintained at Lewiston on the Androscoggin River, at Millinocket on Ferguson Pond, and at Wallagrass on Soldier Pond.

It is intended to gradually accumulate data on the water powers of New England and regarding sites for water power as yet unused, and to have this information generally available for engineers and other parties interested, either in shape of reports or on file at the Washington and district offices.

Lists are appended of the Water Supply Papers and Reports of the Geological Survey that have been published up to the present time: (1) Upon hydrographic methods and investigations of general interest; (2) those containing data on the flow of streams, water powers, etc., of New England.

UNITED STATES GEOLOGICAL PUBLICATIONS RELATING TO GENERAL HYDROGRAPHIC INVESTIGATIONS.

Nineteenth Annual Report, Part IV, 1897, pp. 17–31. "Methods of Measurement."

Twentieth Annual Report, Part IV, 1898, pp. 20–22. "Methods of Measurement."

Twenty-first Annual Report, Part IV, 1899, pp. 28–41. "Methods of Investigation; also, Difficulties in Measuring Flow over Dams."

Water Supply Paper 35, 1899, pp. 11–25. "General Discussion of Methods."

Water Supply Paper 47, 1900, pp. 10–15. "Methods of Using Stream Gagings for the Computation of Water Power."

Twenty-second Annual Report, Part IV, 1900, pp. 49–50. "Methods of Investigation."

Water Supply Paper 56, 1901. "Methods of Stream Measurement."

Water Supply Paper 64, 1902. "Accuracy of Stream Measurement."

Water Supply Paper 76, 1903. "Observations on Flow of Rivers in Vicinity of New York City.

Water Supply Paper 80, 1903. "Relation of Rainfall to Run-off."

Water Supply Paper 94, 1904. "Hydrographic Manual."

Water Supply Paper 95, 1904. "Accuracy of Stream Measurement." (2d ed.)

UNITED STATES GEOLOGICAL SURVEY PUBLICATIONS RELATING TO HYDROGRAPHY IN NEW ENGLAND.

Nineteenth Annual Report, Part IV, 1897, pp. 34–117.

Twentieth Annual Report, Part IV, 1898, pp. 45–47; 64–78.

Water Supply Paper 27, 1898, pp. 9–16.

Twenty-first Annual Report, Part IV, 1899, pp. 50–63.

Water Supply Paper 35, 1899, pp. 25–44.

Twenty-second Annual Report, Part IV, 1900, pp. 56–81.

Water Supply Paper 47, 1900, pp. 29–36.

Water Supply Paper 65, 1901, pp. 13–42.

Water Supply Paper 69, 1902. "Water Powers of Maine."

Water Supply Paper 82, 1902, pp. 11–58; 77–79.

Water Supply Paper 97, 1903, pp. 14–103; 338–355.

Water Supply Paper 124, 1904. Entire.

Water Supply Paper 129, 1904, pp. 139–143.

THE WATER SUPPLIES OF THE NEW YORK METROPOLITAN DISTRICT WITH SPECIAL REFERENCE TO THEIR PURIFICATION.

BY GEORGE C. WHIPPLE, CONSULTING ENGINEER, NEW YORK CITY.

[*Read September 15, 1905.*]

Mr. President, and Fellow Members of the New England Water Works Association, — I don't know how many times you have been told during the last few days that New York is a great city. You heard it from those who gave the addresses of welcome, you read it in the descriptive pamphlet prepared by the committee, and you have had a chance to see something of it for yourselves; and now, lest I be thought lacking in local patriotism, I want to say it again. Yet, after all you have seen and heard, I doubt if even now you have come to fully recognize the bigness of New York. When you went to Coney Island by steamer yesterday you thought, no doubt, that you were leaving the city behind you; yet the Statue of Liberty, which stands far out in the harbor, is really the center of a semicircle which bounds the city limits. From this statue it is 18 miles to the most northerly point of the borough of the Bronx, 18 miles to the most southerly point of the borough of Richmond, and 18 miles to the most easterly boundary of the borough of Queens. The western boundary of the city, formed by the Hudson River, the harbor, and the narrow channels west of Staten Island, is almost a straight line. Of the 500 square miles included in this semicircle, 327 square miles represent the land area of Greater New York. (See Fig. 1.)

NEW YORK METROPOLITAN DISTRICT.

If our eighteen-mile semicircle be extended over New Jersey it will include something over 400 square miles of land surface and about 45 cities and towns in that state. Some of these cities are large and important, as, for instance, Jersey City, Newark, Elizabeth, Hoboken, Weehawken, etc., while the Oranges, Montclair, Engle-

wood, etc., are well-known suburban communities. The New Jersey people are, to be sure, in a different state from New York, yet their relations with the greater city are very close, and when the ferries which now cross the Hudson River shall be supplemented by the tunnels under construction this relation will become

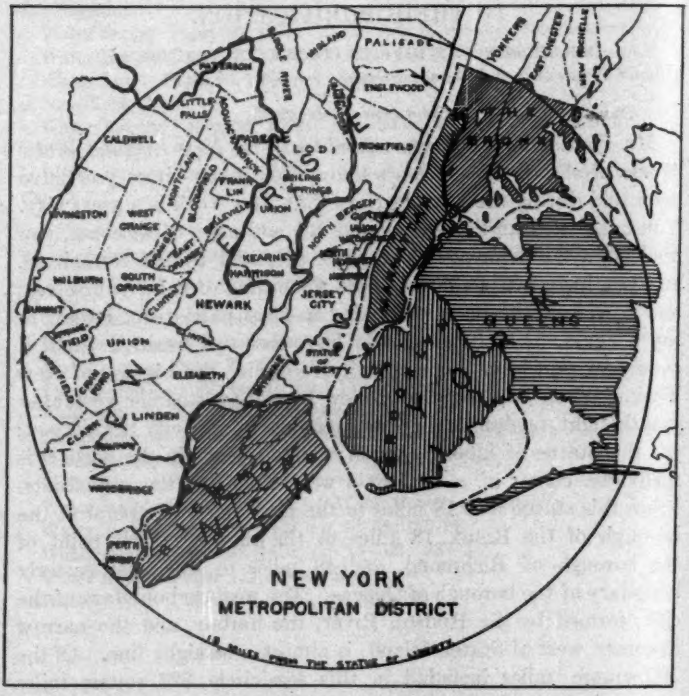


FIG. 1. DIAGRAM SHOWING THE CITIES AND TOWNS INCLUDED IN THE NEW YORK METROPOLITAN DISTRICT.

closer. Thus, while these New Jersey communities are never likely to become a political entity with New York, the region included within the eighteen-mile circle may be not inappropriately termed the Metropolitan District, as it has one vital center and many interests in common.

Outside of this circle on the north side there is a large suburban district which is just as closely connected with the city as the New Jersey townships above mentioned. To include them our radius must be extended to 30 miles. This wider circle brings us to the Connecticut line. Outside of it lie New England and the rest of the world.

The present population of Greater New York is something over four millions. There are at least one million people within the eighteen-mile limit in New Jersey, and there are half a million more people within the north suburban zone of New York. Thus, taking the New York Metropolitan District as a whole, there are at the present time more than five and a half million people who live within thirty miles of the Statue of Liberty. But even these figures do not tell the whole story. New York City is growing at the rate of 27 per cent. every ten years, and the suburban districts around New York are increasing at the rate of more than 30 per cent. In twenty years from now New York City will have a population of six millions, and in the entire Metropolitan District there will be more than eight million people.

To provide this great group of communities with pure and wholesome water, — enough for fire purposes, enough for all domestic, industrial, and public uses, and enough to gratify the American instinct of using a pint and wasting a quart, — is without exception the most gigantic municipal water-works problem of the world.

WATER CONSUMPTION.

New York City is now using upwards of 450 million gallons of water a day, and the entire Metropolitan District is using nearly 600 million gallons, or about 110 gallons per capita. While this figure is higher, perhaps, than it should be, and represents a lavish use and waste of water, yet, judging from common experience, there is reason to believe that in spite of all efforts to stop leakage in the mains, and in spite of all efforts to restrict waste even by the severe method of metering (which, I believe, should and will be ultimately adopted), this per capita consumption is destined to increase instead of diminish during the next quarter of a century. In all probability the district, as a whole, will be using 125 gallons per capita in 1925, while the main parts of New York City may

be using upwards of 150 gallons. If we allow 150 gallons per capita for Manhattan and the Bronx, 125 gallons for Brooklyn and Queens, 100 gallons for Richmond and the rest of the Metropolitan district, then in twenty years from now the total quantity of water needed each day will be more than one billion gallons, or enough to cover a square mile to a depth of 5 feet.

WATER RESOURCES.

Fortunately, the water resources which lie within a reasonable distance of the city are ample to meet this enormous demand if only they are properly developed: in fact, New York is singularly fortunate in this regard. The entire Metropolitan region is situated at a comparatively low elevation; in only a few places does the land lie higher than 200 feet above sea level, and a considerable proportion of the most thickly settled parts is lower than 100 feet. The district is surrounded on the north and northwest by an upland region, where the rainfall is ample, where the facilities for water storage are good, and where the natural quality of the water is excellent. Within 100 miles of the district there are large areas where the land has an elevation higher than 500 feet, and within a radius of 200 miles there are areas where the elevation is even higher. The opportunities for upland gravity supplies are therefore excellent. This highland region lies partly in New York, partly in New Jersey, and partly in Connecticut. Not all of these tracts, however, are available or capable of economical development, and in some cases the danger of interstate complications prevents the carrying out of what would be otherwise advantageous projects. But even after barring out those supplies which are open to legal objections, it remains true that the State of New York can furnish ample water resources for her greatest city, while New Jersey is able to take care of herself in the way of supplying those of her cities which lie within the Metropolitan District.

Besides these upland sources there are other sources of water supply available to the district. On Long Island and Staten Island there are portions of the Atlantic coastal plane, covering several hundred square miles, where vast stretches of sand offer unique facilities for the collection and utilization of ground water.

From these sources there might be supplied, if necessary, all the water needed for the boroughs of Brooklyn and Queens. At present some of these sources are barred out by legal restrictions (*i. e.*, Suffolk County on Long Island), and on account of the necessity of pumping the Long Island water it may be found cheaper, perhaps, to obtain a part of the supply from upland sources rather than to extend the aqueduct indefinitely on Long Island. Nevertheless, the water is there and may be utilized if it ever becomes necessary.

In addition to these sources there is the Hudson River, which passes through the heart of the district, draining an area of more than 12 000 square miles. By filtration at some point above the limit of the run of salt water, it would be possible to obtain a very large quantity of satisfactory water. In the distant future it may become necessary to utilize water from this source.

PRESENT SOURCES OF SUPPLY.

There are at present more than 100 distinct sources of water for the New York Metropolitan District. They include almost every conceivable type of supply, — lakes, large impounding reservoirs, rivers with small storage and rivers with no storage at all, river waters filtered, dug wells, shadow wells, infiltration galleries, ground waters filtered, and surface and ground waters mixed. About half of these sources lie inside the limits of the Metropolitan District, but these local supplies are small and scattered and together do not furnish more than about fifty million gallons a day out of the six hundred millions used by the entire district.

If we classify the supplies according to their sources we find that there are 20 lakes and reservoirs where the storage is large, 17 small storage reservoirs, 11 filtered river waters, 61 ground waters, and 1 ground water filtered. Of the entire supply about 15 per cent. is ground water, 10 per cent. is surface water filtered, and 75 per cent. is surface water unfiltered.

All of the water furnished to Manhattan and most of the water furnished to Brooklyn and the Bronx is supplied by the city, but in Queens and in Richmond the service is quite largely controlled by private companies. In New Jersey, also, private water com-

panies are strongly intrenched, although Newark and some of the other cities control their own supplies.

WATER OBTAINED WITHIN THE DISTRICT LIMITS.

About fifty million gallons of water a day are derived from local sources which are situated inside of the district limits. This is particularly true of the boroughs of Queens and Richmond, where ground water is utilized by means of driven wells scattered over the area. Some of the suburban sections of Brooklyn are likewise supplied with ground water. In Brooklyn some of the ground water is pumped into the distribution pipes and mixed with the Ridgewood water, which forms the main supply of the city; but in Flatbush, the most attractive of Brooklyn's suburbs, the supply is entirely distinct and the excellent quality of the supply is considered by real estate dealers as a valuable asset. Certain portions of the Bronx receive water from local driven wells, and the residential section lying to the north of the city, including Yonkers, Mount Vernon, New Rochelle, Mamaroneck, Port Chester, White Plains, Ardsley, Tarrytown, etc., also receive water from near-by sources. In New Jersey this is true of Elizabeth, Perth Amboy, Summit, and some of the smaller places.

WATER FROM OUTSIDE SOURCES.

By far the greater portion of the Metropolitan District is supplied with water from sources which lie at some distance from the city. (See Fig. 2.) The most important outside sources are seven in number; they are:

1. The Croton River, which supplies all of Manhattan and a part of the Bronx.
2. The Bronx and Byram rivers, which also supply the Bronx.
3. The Ridgewood system of streams and driven wells on Long Island, which forms the greater part of the supply of Brooklyn.
4. The Hackensack River which, from its pumping station at New Milford, supplies the cities of Hoboken, Weehawken, and more than thirty towns and villages.
5. The Pequannock River, which supplies the city of Newark.
6. The Rockaway River, which forms the present supply of Jersey City.

7. The Passaic River, which, from a pumping station at Little Falls, supplies Paterson, Passaic, Montclair, Bayonne, Kearney, Harrison, and other smaller places.

These supplies, taken together, furnish in round numbers about 550 million gallons of water a day.

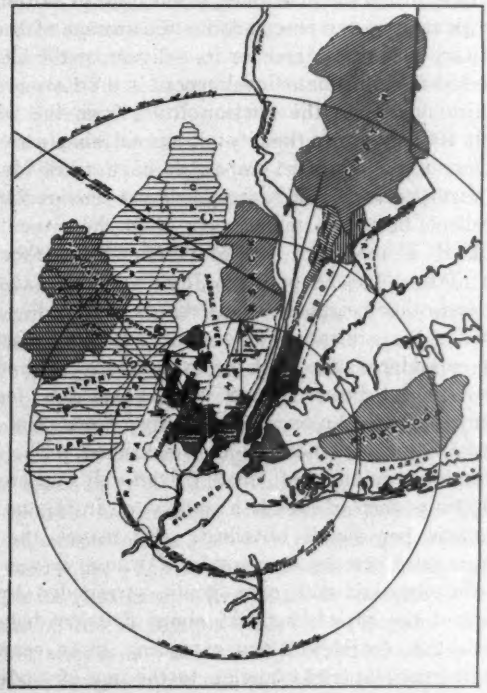


FIG. 2. DIAGRAM SHOWING THE PRINCIPAL DRAINAGE AREAS WHICH FURNISH WATER TO THE NEW YORK METROPOLITAN DISTRICT.

Great as the present sources of water supply appear to be, yet in New York City the consumption has already caught up with the safe yield of the watersheds, and an increased supply is urgently needed. It is unnecessary at this time to describe the various investigations which have been made in connection with

this subject. They have been fully set forth in official reports. It is sufficient to state that steps are now being taken to provide an additional supply sufficient to furnish all the water that New York will need for a generation. The source of supply has been selected; authority for the new work has been obtained; executives have been chosen, and the machinery is being put in motion to construct the gigantic works necessary for the storage of the water, for its sanitary protection, and for its delivery to the city. The source selected for immediate development is the Esopus River, a stream which flows into the Hudson River from the west at a point about 100 miles from the city; it has a drainage area of 255 square miles on the southern slopes of the Catskill Mountains. Here the facilities for storage are good and the quality of the water excellent, better, in many ways, than the present Croton water. It is a supply of which Father Knickerbocker will be proud. After the Esopus, the Rondout, the Catskill, the Schoharie and other neighboring watersheds can be developed.

Projects for the utilization of ground water on Long Island have been considered also, but no far-reaching method of development has yet been decided upon. One new feature of the Brooklyn supply, however, is worthy of mention, namely, the infiltration galleries now being constructed. The borough now has a large number of small driven-well stations on its watershed, from each of which a supply of from one to five million gallons per day is obtained. To reduce the cost of maintenance and increase the supply of water, it was decided to try a tile pipe, laid with open joints, surrounded by gravel, the bottom of the pipe being laid about five feet below mean high tide at the central well and extending, in an easterly and westerly direction, at right angles to the line of underground flow, for a distance of about one and one-quarter miles each way from the central well. The invert of the pipe at the end of the line is about two feet below mean high tide. The pipe is laid with open joints, surrounded by gravel, and it is expected to utilize all the water flowing through the pervious sand strata on the south side of Long Island. The first of these galleries has been located near Wantagh, Long Island. It consists of a 36-inch vitrified pipe at the pump well, gradually reducing to a 20-inch pipe at the end

of the line. Where the gallery passes through the village of Wantagh cast-iron pipe is used to prevent any possible contamination and also to avoid drawing too heavily on the ground water through the village. It is expected to establish six or seven additional galleries, practically paralleling the entire conduit line from Massapequa to the Spring Creek Station, leaving out, however, the territory in the immediate vicinity of the villages of Rockville Center and Freeport.

No projects of any magnitude for the increase of the water supply in New Jersey from outside the limits of the watersheds already mentioned are being considered, but should more water be needed there are numerous watersheds to the north and northwest of the present areas which might be drawn upon.

QUALITY OF THE PRESENT SOURCES OF SUPPLY.

So numerous are the sources that it is difficult to make any general statement in regard to the quality of the water furnished to the Metropolitan District which will adequately express the facts. It may be said, however, that from the standpoint of public health, the water supplies of New York compare very favorably with those of other cities of the country. As a rule, the surface waters are neither extremely high colored nor very turbid, except for short intervals after rains. Like most surface supplies, the water becomes unpleasantly odoriferous during the summer months on account of the growth of microscopic organisms in the storage reservoirs. The average growth of these organisms is, perhaps, somewhat greater here than in the vicinity of Boston; which may be due, in part, at least, to the fact that the stripping of reservoir sites is not as generally practiced in this vicinity as has been the case with the reservoirs of the Boston Metropolitan District. The Croton water often smells bad during the summer, and contains more or less sediment which makes it unsightly. All of the Croton reservoirs were filled without treatment of the sites, and the result has been the establishment of regular growths of algæ of various kinds in all of them, but especially in Croton Lake itself. In Brooklyn the Ridgewood supply is, in general, somewhat less unattractive, but a few years ago its condition was quite as bad as that of the Croton water. What is

true of the Croton and Ridgewood supplies is true in a general way of the other surface supplies in this vicinity which are used without filtration.

The ground waters near New York are generally of good quality, although some of them are hard, and a few contain excessive amounts of iron, while some, which are located near the seacoast, contain large amounts of salt.

From a sanitary standpoint we are in the habit of judging waters by the typhoid fever death-rates of the cities supplied by them. Considering the New York Metropolitan supplies from this point of view, it may be stated that the typhoid fever death-rates in this region are generally low. The average typhoid fever death-rate in New York City, taken as a whole, is about 20 per 100 000, although it varies in different boroughs and is slightly different for different years. As a rule, the annual typhoid death-rates are somewhat below 20 in Manhattan and somewhat above 20 in Brooklyn; in the Bronx they seldom exceed 15; in Queens they are between 15 and 20; in Richmond about 20; in New Jersey the typhoid death-rates have a similar range. In some places they are as low as 10, while in a few cases they are as high as 30. Without going into the figures in detail it may be said that the average death-rate from typhoid fever in those cities and boroughs of the Metropolitan District which are supplied with ground water or filtered water is about 15 per 100 000, while in those boroughs supplied with surface sources not filtered the average death-rate is nearer 20. This fact is not due entirely to the quality of the water, but there is no doubt that the water has much to do with it.

In connection with this use of typhoid fever death-rates as an index of the quality of water, I should like to express my opinion that the time is coming when we shall look not only to the death-rate from typhoid fever but to some of the other health statistics. It is a well-known fact that typhoid fever is by no means the only disease which can be transmitted by water. There is good reason to believe that many of the common intestinal disorders, especially those which affect young children, are caused by bacteria transmitted through the public water supply. Experimental evidence upon this point is not very strong as yet, but in some cases statis-

tics have been obtained which show it to be a fact. It is not certain that the bacteria which cause these troubles are due to actual pollution, and it is quite possible that some of the more common forms of bacteria found in surface waters may be responsible for part of the trouble. Children consume large quantities of milk, and frequently the milk is diluted with water. Therefore, if the water contains objectionable bacteria they are likely to develop in the milk, and their effect, therefore, may be multiplied a thousandfold. When a city changes its water supply from a contaminated water to a filtered water there is an immediate reduction in the deaths from diarrheal diseases, and of children under five years of age. This is often greater than the reduction in the amount of typhoid fever.

As an illustration of this I should like to call attention to some statistics recently compiled from the neighboring cities of Albany and Troy.

EFFECT OF FILTRATION ON DEATH-RATES AT ALBANY AND TROY, N. Y. (DEATH RATES PER 100 000.)

	ALBANY.			TROY.		
	1894-98. (Before filtration.)	1900-04. (After filtration.)	Difference.	1894-98.	1900-04.	Difference.
Typhoid fever	104	26	78	57	57	0
Diarrheal diseases	125	53	72	116	102	14
Children under 5 years	606	309	297	531	435	96
Total deaths	2 246	1 868	378	2 157	2 028	129
PERCENTAGE REDUCTION OF DEATH-RATES.						
Typhoid fever		75			0	
Diarrheal diseases		57			12	
Children under 5 years		49			18	
Total deaths		17			6	

Filtered water was introduced into Albany in 1899. The water supply of Troy has remained practically unchanged.

The figures show the average death-rates for five years before and after the introduction of filtered water at Albany, and the

corresponding death-rates for the city of Troy, where the water supply was not materially changed. It will be noticed that whereas the reduction in typhoid fever amounted to 78 deaths per 100 000, the reduction in diarrheal diseases amounted to 72 deaths and the reduction in deaths of children under five years of age was 297 per 100 000 in Albany. In Troy the reduction in the deaths from diarrheal diseases and of children under five years of age was much smaller. These cities are similarly situated, and their sanitary conditions differ chiefly in their water supplies. It is fair to assume, therefore, that the improvement in the health of the city of Albany was due to the filter which was installed in 1899.

Another table illustrating this fact was presented by Allen Hazen at the International Engineering Congress recently held in St. Louis. It represents results obtained from many American cities and shows that there is a reduction in the total death-rate due to the introduction of filtered water which is much greater than that accounted for by the decrease in typhoid fever. Either the cause of other diseases must have been reduced by the use of filtered water or else the general tone of the public health was improved by the increased purity of the water supply.

	Per 100 000
Reduction in total death-rate in five cities with the introduction of a pure water supply	440
Normal reduction due to general improved sanitary conditions, computed from average of cities similarly situated but with no radical change in water supply	137
Difference, being decrease in death-rate attributable to change in water supply	303
Of this, the reduction in deaths from typhoid fever was	71
Leaving decrease in deaths from other causes attributable to change in water supply	232

In New York, and especially in Brooklyn, diarrheal diseases akin to typhoid fever are sometimes quite prevalent, and while there is no direct proof as yet, there is reason to believe that these are in some way associated with the quality of the water. The death-rate of children under five years of age is also somewhat high in our city. There are, no doubt, many reasons for this, but among them the quality of the water supply is certainly not the least.

While the water supplies of New York are reasonably free from pollution and while the supervision is fully as elaborate as exists in most American cities, yet, with so large an area of watershed to be covered, it is manifestly impossible to completely eliminate all contamination, and as time goes on the effect of this will materially increase.

Public opinion is beginning to crystallize in regard to the matter, and the need of filtering the main supplies of New York and Brooklyn is gradually being appreciated. The advantages of filtration in this city are unmistakable and it is to be hoped that when the New England Water Works Association again meets here we shall not be obliged to apologize in any way for the quality of the water which runs from our service taps, but that we can present you with a glass of water drawn from our city mains equal in quality to that of any city in the country. Years ago the Croton water had an enviable reputation among American cities. Its supremacy has been lost not through its own deterioration, but because of the improvement in the supplies of other cities. There are sound sanitary and economic arguments in favor of filtration, but, even putting these aside, it is to be hoped that for the sake of civic pride alone this supremacy may be regained. Filtration of the Croton water, coupled with the magnificent new supply which is to be derived from the Catskill Mountains, will give our great American metropolis almost the best large water supply in the world.

FILTRATION IN THE VICINITY OF NEW YORK.

Notwithstanding the fact that the water of New York City is not filtered at the present time, there is probably no better place in the country to study the development of water filtration than in the immediate vicinity of this city. Within a radius of seventy-five miles can be found the first slow sand filter constructed in this country, and the first mechanical filter ever put into operation for a municipal plant. There can be found, also, types of the most modern slow sand filters, and mechanical filters which embody many of the latest ideas. Between the earliest and simplest types of filters and the latest and more modern types, many other kinds may be found which represent different stages

in development and which embody differences in design in order to adapt them to various kinds of waters.

I will now refer briefly to some of the various filters which are to be found in this locality. There will not be time to consider any of them in great detail, but the descriptions will serve to give an idea of what is going on around New York in the way of filtration.

POUGHKEEPSIE, N. Y.

The filters at Poughkeepsie were the first sand filters built in the United States. They were designed by James P. Kirkwood in 1872. The old filters are still in use, but in 1896 they were enlarged to provide for the increased consumption in the city. The filters as originally constructed were not covered, but during the past year covers have been added in order to get rid of the trouble which has been experienced in removing ice from the sand beds during the winter. The filters treat the water of the Hudson River, which, at Poughkeepsie, is considerably polluted, and which is frequently too turbid to be satisfactory as a drinking water.

The Poughkeepsie filters were described in a paper by the superintendent, Charles E. Fowler, which was given before this association and which may be found in Vol. XII, page 209, of the JOURNAL.

HUDSON, N. Y.

The filters at Hudson were built in 1874, two years after those at Poughkeepsie. They also were designed by James P. Kirkwood. In 1888 they were enlarged, but since that time the consumption has considerably increased, and they are not now sufficient to satisfactorily purify all the water which the city uses. The filters treat the water of the Hudson River, which is muddy and contaminated, as it is at Poughkeepsie. An account of these filters, prepared by H. K. Bishop, superintendent of public works, was given in the *Engineering News* of August 14, 1902.

There are two filters, designated the "old" and the "new." The old filter has an area of about 9 000 square feet. The new filter, which is at a somewhat higher elevation, has an area of 23 000 square feet. The old filter is practically a storage reservoir with the lower half occupied by the filtering material. The filtered water passes from it to a clear water basin adjacent to it. This

FIG. 1. OLD FILTER AT POUGHKEEPSIE, N. Y., SHOWING REMOVAL OF ICE.

FIG. 2. INTERIOR OF COVERED FILTER AT POUGHKEEPSIE (UNCOMPLETE).

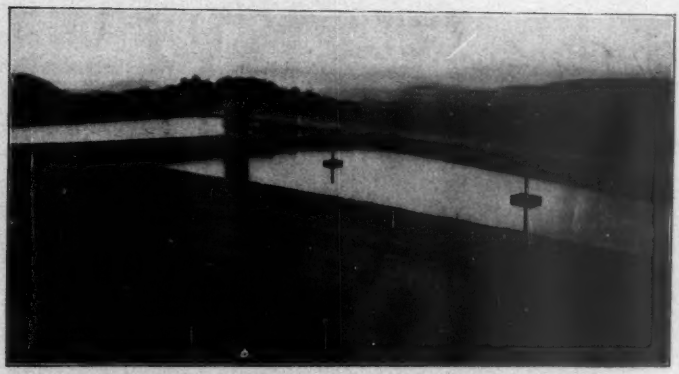


FIG. 1. OLD FILTER AND CLEAR WATER RESERVOIR AT HUDSON, N. Y.

FIG. 2. OLD FILTER BEDS AT FAR ROCKAWAY, LONG ISLAND.

clear water basin also receives the filtered water from the new filter, located above it. The new filter is now in process of reconstruction.

HEMPSTEAD, L. I.

The filter at Hempstead, L. I., while of recent date, is perhaps the simplest type of filter in use in the New York Metropolitan District. It consists of an area of natural sand surrounded by earth embankments, and under-drained with a rectangular system of tile drains which discharge through a main collector into Hempstead Pond, which is adjacent to the filter and somewhat below it in elevation. From this pond the water flows by gravity into the conduit. This filter treats part of the water of Hempstead Stream, which becomes much polluted as it passes through the village of Hempstead. In its purpose and general construction it resembles the Pegan filter at Natick, Mass., which treats the water of Pegan Brook. The beds have an area of 0.6 acre each and are designed to filter between 2½ and 3 million gallons per acre per day. The sand, which was found *in situ*, has an effective size of .27 mm. The drainage system consists of an 18-inch main pipe laid at one side of the bed, with 6-inch laterals running across the bed, 108 feet long and 10 feet apart. These pipes are surrounded by coarse gravel 18 inches wide and 16 inches deep, with 21 inches of fine gravel on the top. The high-water elevation on the filters stands about 7 feet higher than the maximum elevation of the pond into which the effluent discharges. The discharge is controlled by weirs on the effluent pipes. The total cost of the beds was $11 000. This low cost was due to the simple form of construction and to favorable conditions at the site.

Not only are these filters simple in construction but they are also operated in a simple manner. The water flows through them with almost no regulation and the attention required is therefore very little. When the surface of the filter becomes clogged the sand is not removed in the usual way by scraping, but, instead, the sediment is washed off by means of flowing water applied to the surface. For this purpose planks are set on edge so as to divide the filter longitudinally into channels 15 and 20 feet wide. Raw water from the adjacent filter is then allowed to flow slowly down these channels, the surface of the sand being raked meanwhile in

order to loosen the sediment so that it will be carried away with the flowing water. The rate of flow is so adjusted that practically no sand is lost, and the result is said to be practically as good, so far as it affects the efficiency of the filters, as the more expensive method of scraping the sand and washing it. This method of scraping is a novel one in this country although it has been used to some extent abroad. While it may be applicable in this case, it is doubtful if it would work satisfactorily with waters which contain sediment composed chiefly of clay.

The cost of operation, including interest charges and all materials and labor, is estimated by the water department as $1.04 per million gallons. Of this about two thirds represents interest on the investment. The bacterial efficiency of the filter is excellent. The number of bacteria in the raw water varies from 200 or 300 up to 8 000, but it is seldom that the number of bacteria in the filtered water exceeds 50.*

FOREST STREAM, L. I.

The filters at Forest Stream are somewhat similar to those at Hempstead, having no water-tight floor and having the side walls constructed of earth embankments. They are similar also in having no elaborate system of regulating the flow. They differ, however, from the Hempstead filters in that the filter bed is not a natural one but is made of washed sand. As the filters are at a somewhat low level compared with the ground water table and as there is no filter floor, the drains collect some ground water, but thus far no trouble has been experienced from this source. The beds were constructed by excavating to the desired grade and placing 6 inches of coarse gravel and 2 inches of fine gravel over the bed. Below the laterals the bottom was excavated so as to have drains 18 inches wide and 8 inches deep in which coarse gravel was placed. Coarse and fine gravel was also placed above the laterals. The filter beds have a combined area of 2.5 acres, and are three feet deep. The sand itself has an effective size of .28 to .30 mm. Most of it was obtained by washing material taken from the excavation.

*These and other data regarding the Brooklyn filters were kindly furnished by Mr. I. M. de Varona, chief engineer, department of water supply, gas and electricity.

FIG. 1. SAND FILTER AT HEMPSTEAD, LONG ISLAND.

FIG. 2. SAND FILTER AT HEMPSTEAD, LONG ISLAND, SHOWING EFFLUENT DISCHARGING INTO HEMPSTEAD POND.

The operation of the beds is controlled by a pump. At the present time the beds are cleaned by scraping, but it is intended to make arrangements by which they can be washed as in the case of the Hempstead filters. The efficiency is said to be good. The number of bacteria in the raw water varies from 400 to about 8 000, while the number of bacteria in the effluent is ordinarily below 50 and seldom more than 200. The quantity of water filtered varies from 2 to 3½ million gallons per acre per day. The original cost of this plant was $40 000.

FAR ROCKAWAY, L. I.

Far Rockaway, an important suburban community in the borough of Queens, and also a somewhat noted summer resort, is supplied with water from driven wells, which is filtered in order to remove the iron it naturally contains. These filters were constructed in 1896. The plans were drawn by Allen Hazen, consulting engineer. The original plant consisted of two sand beds, which had a combined area of 40 000 square feet. The sand used was natural sand, found in the immediate locality. Before the water passes over the beds it receives a certain amount of aëration by spilling over the edge of an upright pipe. This aëration serves to remove the free carbonic acid from the water and to oxidize the iron which is present so that it really precipitates in the form of ferric oxide. This precipitation occurs over the sand bed and there is formed on the top of the sand a thick brown layer, while the water leaving the filter is almost free from iron and perfectly satisfactory for domestic use. As the filters are open, filamentous algæ develop in great numbers on the top of the sand, and the iron rust becomes mixed in with them to such an extent that when the beds are cleaned there is a tenacious scum on the sand which may be rolled up like a carpet. This materially increases the ease with which the beds are cleaned. A full description of this filter plant as first constructed may be found in the *Engineering News*, April 12, 1900. Recently the plant has been enlarged under the direction of the chief engineer, Mr. Charles R. Bettes.

NYACK, N. Y.

The village of Nyack is situated on the west bank of the Hudson

River, 28 miles from New York City. Its water suppply is taken from one of the tributaries of the Hackensack River. Slow sand filtration was introduced in 1899. The general plans were drawn by Allen Hazen, consulting engineer, in 1897, but were afterwards modified somewhat by L. L. Tribus, to adapt them to local conditions.

There are two beds, 160 feet by 120 feet. The sand is 3 feet thick, resting on 1 foot of gravel. The present consumption is 650 000 to 700 000 gallons per day.

This filter was described in the *Engineering Record*, April 28, 1900.

YONKERS, N. Y.

The filter plant at Yonkers was constructed in 1903 from plans and specifications also drawn by Allen Hazen, consulting engineer. The plant was designed to fit special conditions, and for this reason it differs somewhat from the ordinary layout. It is a slow sand filter with two beds of about one-half acre each, and a clear water reservoir which holds about 200 000 gallons. The filters are not covered. The level of the filtering surface is below the water level of the river and water is delivered to it by gravity. From the collecting drains water flows to the clear water well and is then pumped to the distributing reservoir, the pumping station and filter being on opposite sides of the river. The filter was not covered as it was not expected to be used much during the winter. The filter is provided with the usual appurtenances for washing sand, etc. The results obtained by this filter are excellent. Description of it may be found in the *Engineering Record*, July 2, 1904.

ALBANY, N. Y.

Although Albany is at some distance from the New York Metropolitan District, yet references to filters in this vicinity would not be complete unless this plant were mentioned. It was built in 1899 by Allen Hazen, chief engineer, and its construction marked an epoch in water filtration in this country. It stands as the prototype of our American modern methods of slow sand filtration, and many filters have since been built along similar lines. A full description of the filter was given by Mr. Hazen in the Trans-

actions of the American Society of Civil Engineers for the year 1899.

The plant has given excellent satisfaction and has resulted in the improvement of the health of the city as already pointed out.

POUGHKEEPSIE STATE HOSPITAL.

A much smaller but equally interesting filter of the covered slow sand filter type is that which has recently been put in operation at the state hospital at Poughkeepsie. This filter treats the water of the Hudson River as does the city filter at Poughkeepsie. The filter consists of two beds which have a combined area of one third of an acre; its nominal daily capacity is about one million gallons.

The most interesting feature in connection with this filter is the arrangement for washing the sand. The sand court, instead of being located beside the filter beds, is placed upon the roof, which at this point is reinforced with steel. By means of a portable ejector the dirty sand scraped from the bed is forced at once to a sand washer, where it is washed by means of an upward current of water. This washer is somewhat higher than the floor of the sand court, upon which the clean sand falls and where it it is stored ready to be replaced in the sand beds when needed.

The sand washer deserves more minute description. It consists of a concrete box with five compartments. The dirty sand, mixed, of course, with the water from the ejector, enters a compartment in one corner and flows over a weir into the second compartment. At the bottom of this second compartment there are several lines of perforated brass pipe through which water is admitted. The upward velocity of the water washes the sand and carries with it the fine particles of dirt which remain in suspension while the sand itself naturally works its way across the sloping bottom of the compartment to an outlet through which it passes and falls upon the sand court. The dirty water flows over a weir on one side into the third compartment and then successively into the fourth and fifth compartments. These serve to prevent the loss of the smaller sand grains. The dirty water, of course, passes eventually to the sewer. This method of sand washing is very simple and eminently satisfactory and seems destined to

replace the more complicated method of washing by means of the sand operators of the ejector type as shown in connection with the Albany filters.

This filter was designed by Allen Hazen, consulting engineer, and a complete description of it may be found in the *Engineering Record*, January 7, 1905.

PRIVATE ESTATE ON THE HUDSON.

Another interesting slow sand filter is located not far from the one just mentioned and also treats the water of the Hudson River. It was designed by Messrs. Hering and Fuller. In this case, however, the situation required that the water should not only be pure and wholesome but that it should be also absolutely clear of all color and turbidity. The water is used on the country estate of one of our well-known millionaires. It is used for drinking and for bathing purposes as well, and in this case the requirements for the latter purpose were far more stringent than for the former. The accompanying photograph, Plate IV, Fig. 1, shows the bathing tank lined with white tiles, and in this tank the slightest trace of color or turbidity would be quite noticeable and would seriously offend the esthetic tastes of those who bath in this luxurious manner.

In order to obtain a water which will meet all the conditions it was necessary to use alum as a coagulant. The plant consists of a settling basin, filter beds in duplicate, and a clear water reservoir, all of which are covered. Practically the entire plant is of concrete construction. This filter is interesting as it represents an intermediate type between slow sand filtration and mechanical filtration.

SOMERVILLE, N. J.

The first mechanical filter used in this country in connection with municipal supplies was located in Somerville, N. J. It was constructed in 1885, under the old Hyatt patents. The original filters have been removed and their place has been taken by other pressure filters furnished by the New York Continental Jewell Filtration Company.

LONG BRANCH, N. J.

The water supply of Long Branch is furnished by the Tintern

FIG. 1. SWIMMING TANK ON PRIVATE ESTATE ON HUDSON RIVER, SUPPLIED WITH FILTERED WATER FROM A MODIFIED SLOW SAND FILTER.

FIG. 2. PUMPING STATION, COAGULATION BASIN, AND FILTER, PRIVATE ESTATE ON HUDSON RIVER.

Manor Water Company. The plant consists of twelve gravity filter units and three pressure filter units, each of which has a capacity of one million gallons per day. The quantity of water now filtered, however, is only seven million gallons a day. All of the filters were supplied by the New York Continental Jewell Filtration Company.

MAMARONECK AND POCANTICO.

At each of these places there are pressure filters which have a capacity of about two million gallons a day. The steel filter tanks are 25 feet long and 8 feet in diameter. In the case of Pocantico there is an 85 million gallon storage reservoir from which the water flows by gravity to a coagulation tank 20 feet in diameter and 20 feet high, after which it flows by gravity through the pressure filters to the pumping engines. These works are controlled by the New York Interurban Water Company. The water from the Mamaroneck filters supplies Mamaroneck, and those of Pocantico supply Tarrytown, North Tarrytown, and some of the villages in that section. The water supplies of Larchmont and Portchester are also filtered.

SPRINGFIELD, L. I.

Two of the streams which form a part of the Brooklyn water supply are filtered by mechanical filters before the water is pumped into the aqueduct. One of these is located at Springfield Pond and the other at Baiseley's Pond. These filters were built on plans furnished by the contractors, the specifications requiring, however, certain results as to bacterial purification, amount of coagulant, etc. This method of obtaining filters proved to be far from satisfactory. The filters first furnished failed to meet the required tests and had to be rebuilt, while the initial cost was very high. The plans originally used were modified under the direction of George W. Fuller, consulting engineer, and Robert Spurr Weston. At the present time both plants are giving excellent results, but this can be attributed more to good management than to original design. Both plants are likely to demand heavy outlays for depreciation.

The plant at Springfield has a nominal capacity of three million gallons a day. It consists of two sedimentation tanks, six filter

tanks, and one filtered water tank, all made of wood. The plant has also the usual tanks for preparing the solution of alum which is used as a coagulant. The efficiency of the plant is said to be excellent, the average bacterial removal being about 98.5 per cent., while the amount of alum used is ordinarily less than 1 grain per gallon, although at times more than 2 grains are necessary. On account of the low alkalinity of the raw water it is necessary to occasionally use soda in addition to the alum. The amount of wash water is generally between 4½ and 6 per cent. The cost of filtration at this plant is said to be $8.91 per million gallons, of which $2.89 represents interest and sinking fund, $4.35 labor, and $1.57 materials including chemicals. No allowance, however, was made for depreciation.

A description of this filter, as well as the one at Baiseley's, may be found in the *Engineering Record*, August 26, 1905.

BAISELEY'S, L. I.

The filter plant at Baiseley's Pond, L. I., is a practical duplicate of the one at Springfield Pond, but its nominal capacity is 5 million gallons per day instead of 3 million gallons. This filter is somewhat more difficult to operate than the one at Springfield on account of the occasional presence of immense growths of algæ in the raw water. This has a very important effect on the amount of wash water.

Mr. D. D. Jackson has already described how the use of copper in Baiseley's Pond has improved the operation of this filter.

The cost of filtration at Baiseley's during the last six months of 1904 was said to be $6.46 per million gallons, which included $2.21 for interest and sinking fund, $2.53 for labor, and $1.72 for other supplies, but which did not include depreciation.

LITTLE FALLS, N. J.

The Little Falls filter is well known as the first large mechanical filter constructed on modern lines in the United States. It was built in 1899 by the East Jersey Water Company from general plans prepared by George W. Fuller, consulting engineer, and Chas. L. Parmelee, civil engineer. The nominal capacity of this plant is 32 million gallons a day. This plant is so well known and has

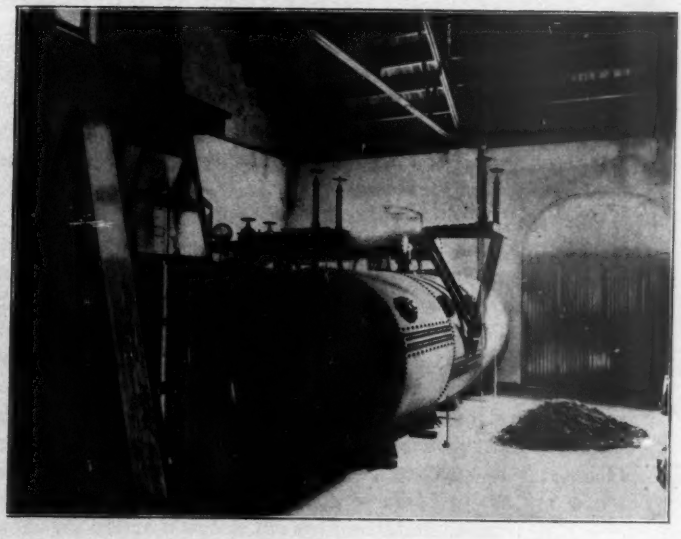
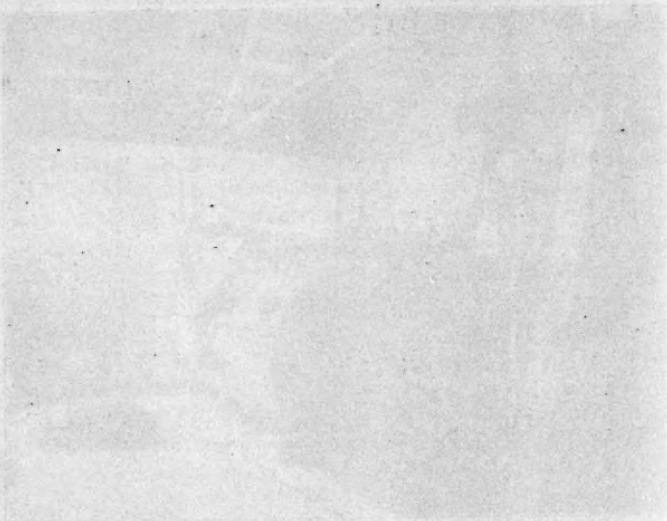
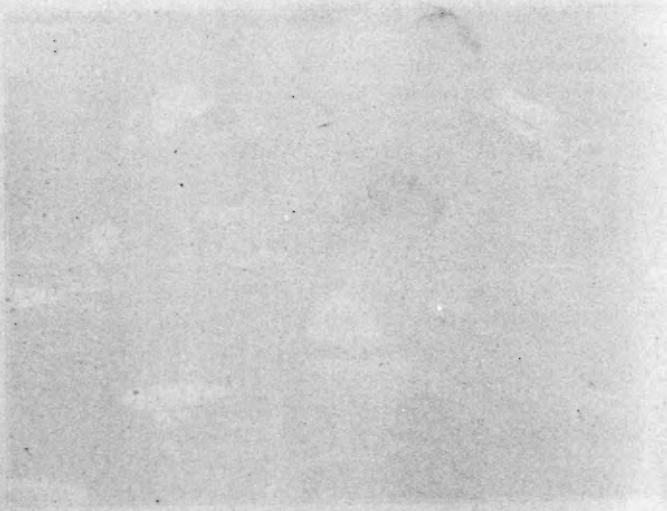


FIG. 1. MECHANICAL FILTER AT MAMARONECK, N. Y.

FIG. 2. MECHANICAL FILTER AT BAISELEY'S, LONG ISLAND.





been so frequently described that it is not necessary to present here a detailed description. It is sufficient to state that in operation it is giving excellent results. A very complete description of this filter, by Mr. Fuller, may be found in the Transactions of the American Society of Civil Engineers, Vol. l, page 394, 1903.

HACKENSACK FILTER.

The second largest mechanical filter in this country is now being completed at New Milford, N. J. It is being built by the Hackensack Water Company and was designed by George W. Fuller, consulting engineer. It is expected to be put into operation next month. This plant has a nominal capacity of 24 million gallons a day. Water is pumped from the conduit from the Hackensack River into a sedimentation basin, where it passes from one end to the other and flows to the filters by gravity. The filters consist of eight beds, each of which has a capacity of three million gallons a day. The alum solution is added to the water in the gatehouse before it enters the sedimentation basin.

There are several unique features in connection with this plant. Perhaps the most conspicuous is the concrete wash-water tank, located outside the filter house. This is built of reinforced concrete and has a capacity of 110 000 gallons. It is 43 feet in diameter and 10½ feet deep, and about 30 feet above the filter. Its walls are 12 inches thick. Under this tank are 8 steel cylindrical tanks for holding compressed air which is used in washing the filter. The wash-water pumps and air compressors are both driven by Pelton wheels. The tanks for mixing and applying the chemicals are located in one end of the building on the second and third stories. There is also a well-equipped laboratory for looking after the operation of the plant.

The filter beds are of unusually large size. A new style of strainer is used, constructed largely of concrete with perforated plates. On account of the large size of the beds, especial care has been taken to secure a uniform distribution of water and air. It has been the intention to eliminate patented devices from this plant as far as possible.

A complete description of this plant may be found in the *Engineering Record*, November 12, 1904.

THE USE OF COPPER SULPHATE AND METALLIC COPPER FOR THE REMOVAL OF ORGANISMS AND BACTERIA FROM DRINKING WATER.—A SYMPOSIUM.

[*September 15, 1905.*]

The Use of Copper Sulphate as an Algicide.

BY DR. GEORGE T. MOORE, WASHINGTON, D. C.

Members of the New England Water Works Association,—I am very glad indeed to have an opportunity of meeting with you here to-day and to open this discussion, which, I hope, will be most profitable to all of us. As I understand it, I am simply to introduce the subject and furnish the basis for the more important papers which are to follow. For this reason I shall run over very briefly the history of the work in this country, and I shall hope to bring up any special points at the end of the discussion rather than at the beginning.

It is not necessary for me to refer to the effect on water of the plants known as algæ. Most members of this association know of the condition produced by these organisms, many from personal experience. My experience began some seven or eight years ago when I lived in New England and had occasion to come in personal contact, as it were, with waters affected in this way.

The first piece of scientific work which I had occasion to publish related to the life history of uroglena; the material for study I obtained at Norwood, Mass., where I had opportunity to note the condition produced in water by this plant.

After leaving Cambridge and going to New Hampshire, I was still engaged upon the problem of algal pollution, and I tried a considerable number of experiments, but because the material with which I had to work was limited, the matter ran along without much being accomplished, and after a year or two I went to Washington.

In that fall, arrangements were made with the Massachusetts State Board of Health to establish a temporary laboratory in the

State House, and Mr. Kellerman, who has been associated with me in this work, and I went to Boston and spent some two or three months there. The facilities there for procuring organisms which produce trouble in water supplies were very good indeed, and we had an opportunity to carry on experiments which, under ordinary circumstances, would have required years of preparation in order to elaborate the machinery for getting the proper samples. We were, therefore, able to obtain results which might have required very much longer had we not enjoyed the courtesies extended by the Massachusetts State Board of Health.

Our idea was, of course, to find something which would be more efficient, cheaper than any method then known or used or recommended by engineers for the destruction or prevention of the growth of algæ in water supplies, and, of course, harmless. The most profitable line of research seemed to be one involving the use of some substance which was toxic to the plants themselves, but which could be used in such minute quantities that the question of the effect upon man would be one which could be eliminated.

Of course, the work of Naegeli, Israel, and Klingman, and other early investigators in physiology, furnished us a basis. Although a large number of substances were tried, it was very soon seen that the heavy metals were going to be the things which would prove most toxic in the smallest quantities. Gold and silver naturally had to be eliminated on account of the expense, although silver, particularly in minute quantities, is very toxic to these forms. Mercury had to be left out, of course, on account of its poisonous effects upon man; and it was a very simple process of elimination to arrive at copper as the thing which warranted the most extensive experiments.

The first report which was ever presented by us on the use of any toxic substance for the destruction of algæ was a confidential report submitted to the Massachusetts State Board of Health some four years ago this winter.

The first practical use of copper sulphate as an algicide was in connection with water-cress beds in Virginia. Here, after the first crop of cress was cut, the remaining plants being very small and growing in water from a thermal spring with a temperature of about 70° the year round, the conditions were most favor-

able for the growth of algæ. Great carpets would form over the beds and smother out the young and delicate cress, causing the loss of about half the crop. The beds were perhaps two hundred yards wide and a quarter of a mile long, cut off by temporary dams for the purpose of flooding the cress in case of freezing weather.

The copper was first applied by a spray pump in the form of a strong solution. It seems ludicrous now that we should have attempted to do it in this way, but the general practice of using germicides and fungicides led us to try it. Wherever the solution came in contact with the algæ it killed them, but the copper was thrown out of solution before it penetrated the great mass of algæ and the result was not satisfactory. It, therefore, became necessary to use some other method, and applying the copper sulphate in crystal form, tying it up in a bag and dragging it back and forth through the water, was resorted to.

The solution used in this particular case was very dilute, being about one to fifty million. The conditions were extremely favorable, on account of the temperature of the water, for getting the highest toxic effect possible, and the elimination of the algæ with this dilution was complete. As a matter of fact, after the first treatment, which completely cleared the beds of the growth, it was not necessary to resort to it again for about six months, and at that time the quantity was decreased so that eventually, although copper was applied every six or eight months as a matter of precaution, it really was not at all necessary. But, as I said, this was a condition where everything was extremely favorable for the use of the copper method.

Later, other opportunities occurred for testing the method in various water supplies, and most of you must be more or less familiar with the results of the use of copper sulphate for the detruction of algæ in reservoirs. It is not necessary to refer to these cases at this time, although I hope that questions during the discussion will bring out points regarding such treatment.

Just a word in regard to the limitations of the method. Of course, the whole process is dependent upon a specific quantity of copper in solution, very minute to be sure, coming in contact with the algæ, or being in such a condition as to be absorbed by

these plants. In a closed reservoir through which there is no very great current, and where the water does not change very rapidly, the conditions are naturally very much more favorable than they would be in a supply where the water changes frequently and the current is considerable. Most important of all is the question of the selective toxicity of the organisms themselves. I refer to this because not a great while ago a very eminent authority in this country, in discussing this very question of the use of copper sulphate, made the statement that it was a well-known fact that all organisms responded in precisely the same way to all toxic substances. Certainly neither our practical experience nor theoretical knowledge regarding the use of copper in the destruction of algæ bears out that statement. As we have tried to point out from the very first, some organisms are very much more susceptible to the action of copper than others, and it is absolutely essential that we know the specific plant to be destroyed, before any definite recommendation can be made. It may mean the use of copper sulphate at the rate of one part to fifty million parts of water, it may mean using it at the rate of one part to one million, or it may mean that it cannot be used at all; because there is no question that certain organisms are so resistant to the action of copper that under ordinary circumstances it is not practicable to resort to this method.

It is conceivable that a large reservoir might be polluted with a certain alga which would naturally be so resistant to the action of copper sulphate that it would not be practicable to use it. Fortunately, however, the organisms which generally occur and which, certainly in this country, are most abundant and produce the worst odors and tastes, are the most susceptible to the action of copper. The same is true regarding the pathogenic germs, those of typhoid and cholera being among the most susceptible organisms to the toxic effect of copper. The fact that these germs do not form resistant spores makes it possible to resort to the copper method.

It is absolutely essential to have a microscopical examination in order to determine the algæ responsible for the difficulty before any definite prescription can be given. From the very first, every effort has been made to emphasize the fact that the use of copper

sulphate for the purification of a water supply, or the destruction of algæ anywhere, cannot be considered a general shotgun method. It must be used intelligently. Although there still exists a difference of opinion regarding the possible harm from copper, there can be no doubt about the fact that a man should have all the necessary information before resorting to copper, and most important of all, for the destruction of algæ, is to know the form which is to be destroyed.

The question of the presence of fish in the water is one which ought to be considered. Of course, fish vary in the same way that the algæ do, so far as their susceptibility to the action of copper is concerned. An interesting case will illustrate this, I think. A game club in northern New York had a large lake which, although originally stocked with bass, had come to contain pickerel in large quantities; consequently, when the members of the club fished in this lake for bass, they continually caught pickerel, and it was a great source of annoyance to them. The lake was polluted with *anabæna*, and it was decided to treat with copper sulphate. It was suggested to me that if some means of getting rid of the pickerel at the same time could be devised, it would be ideal. Never having attempted anything of the kind, no responsibility regarding the result could be taken, but the management was willing to experiment. We did know that bass were among the most resistant fish to copper, standing one part to one hundred thousand in the laboratory with no signs of discomfort. About the pickerel we knew little or nothing. Twice the dose which would have been used to exterminate the *anabæna* was applied, and the pickerel were taken out in such quantities as to practically eliminate them, while I believe only one bass was found dead. This is not referred to as a practice which should be encouraged by any means, but it does, I think, illustrate most beautifully the difference in the toxic effect of a given solution upon two different kinds of fish in the same reservoir, where the temperature, character of the water, and other conditions must have been absolutely the same. Nobody knows how many bass were in the lake, but certainly some thousands.

It should be borne in mind, then, that if a reservoir is stocked with fish very susceptible to copper and at the same time is pol-

luted with algæ very resistant to this metal, it is usually impossible to resort to the method, because a strength of copper necessary to eliminate the algæ would also kill the fish. Fortunately, however, this condition is more or less theoretical rather than actual, as has been shown by practical experience. Take, for instance, the Butte, Montana, case. There the reservoir was stocked with what they called mountain trout, a fish which is supposed to be very susceptible to copper, experiments showing that one part in five or six million will kill such fish. In that particular case they were fortunate in having as the polluting alga *anabæna*, which was completely destroyed by using one part of copper to eight and one-half million parts of water, without, so far as I know, injuring a single fish. The Bureau of Fisheries has been carrying on recently some experiments with copper sulphate for cleaning up breeding ponds of fish, and the results ought to throw considerable light upon the subject.

There are a number of other phases of the question which should be considered. I have not had time to refer to the temperature question, although, of course, it has been brought out in publications that the higher the temperature of the water the greater the toxicity. We have had very few opportunities for treating supplies in the winter time. In one case, however, where the application was made through the ice, the results were entirely satisfactory; but the organism destroyed was *uroglena*, a form which unquestionably is very susceptible to copper, perhaps as susceptible as any of the algæ.

The whole matter seems to resolve itself into this: The more commonly distributed algæ, such as some of the blue-greens, *uroglena*, and certain of the grass-green forms, which are usually responsible for trouble in a water supply, are likewise the most susceptible to the action of copper, and on account of this very fortunate condition of affairs the method has a practical application far beyond what it might have.

The question of the possibility of using copper to such an extent as to produce a resistant strain of algæ has been raised, and, of course, is a proper point to be considered. The fact of the matter is, however, that the whole aim and intention in using copper as an algicide is to so completely destroy the algæ as to leave nothing

from which to breed a resistant form of organisms. If the application is made at the proper time and under the proper conditions, certainly all of those organisms which are susceptible to copper will be destroyed. With spore-bearing algæ or where the organisms are buried in the mud, there cannot by any possible means be any effect from a treatment with copper sufficient to form a more resistant lot. So far as our experience goes, where copper has been used for the destruction of certain susceptible forms, conditions certainly seem to indicate that it requires a less and less amount to keep the water free from this specific organism, rather than an increasing quantity. Experience only can settle this matter, but there is no evidence at the present time to sustain this objection.

Just one other point and I will conclude. Theoretically, we find that many of the algæ respond to very definite toxic doses of copper in the laboratory; that is, working with test tubes or large aquaria, we are able to determine the amount of copper which will destroy any of the common algal forms occurring in water supplies. In actual practice it has been found that the amount of copper necessary to produce the toxic effect is not nearly so large, and this has been under conditions about which there could be no question. That is, most careful estimates of the capacity of the reservoirs being treated were made; there was not at the time the copper application was made any water passing through the reservoir, and the temperature and everything of that sort were taken into consideration. It certainly seemed that at least some of the theoretical data regarding the action of copper upon algæ, as well as its action upon pathogenic germs, which have been published, would have to be modified when used as a basis for practical work. Fortunately, however, the modification will involve a decrease rather than an increase in the amount of copper to be used.

This is not what is usually expected, and the only explanation appears to be that in the laboratory we are dealing with more resistant forms. It is very probable that algæ brought into a laboratory, grown under artificial conditions, become more resistant to any toxic substance. The reasons for this cannot be gone into in detail, but we know that a great many of the weaker forms

die out in the laboratory, and in almost every case it seems probable that the forms upon which the experiments have been tried were really exceptional forms and not those with which we have to deal in a practical way.

I am sure the papers which are to follow will bring out points specifically, and emphasize important things in a way which I have not been able to do, and I hope that in the discussion, and with a free opportunity for asking questions, we all will gain a great deal of valuable information.

The Use of Copper Sulphate to Guard Against Typhoid Fever Epidemics Coming from Unfiltered Surface Water Supplies.

BY PROF. W. P. MASON, TROY, N. Y.

Mr. President and Gentlemen, — I am somewhat embarrassed by the magnitude of the title of my paper, which I had not seen before. I have but a few words to say on this subject and will occupy but a minute or two.

And, first of all, I wish to state that I have nothing but the pleasantest things to say with reference to the use of copper sulphate for the purpose of killing algal growths. I had expected to be instructed to no small degree on the question of killing typhoid germs, but that subject was hardly touched upon in Dr. Moore's remarks. There is no question whatever that we are under very great obligation to Dr. Moore and his associates for giving us some means of getting over the exceeding difficulty of algal growth; but one or two thoughts occur to me with reference to the typhoid side of the question.

You know both the daily and the scientific papers have been quite full of suggestions for the possible cure of the typhoid evil by dosing our water supplies with copper sulphate, following out the general lines already touched upon for dealing with another form of growth. Personally I should scarcely be willing to dose a

water supply for which I was responsible with the intent to kill germs of typhoid, simply because such dosing would have to be continuous. I ask you, is there not a tremendous difference between an occasional dosing, such as would rid water of these ordinary algal growths, and the continuous dosing required to dispose of an organism like the typhoid germ?

If we have a bad taste in our reservoir water, it is there but occasionally, while if we have sewage in our supply it is present three hundred and sixty-five days and nights in the year. Therefore, although the amount of copper sulphate added be small, the important point is that, when we are dealing with the typhoid germ, its addition must be continuous. I will admit that in the event of Asiatic cholera striking us, a disease which comes to us but rarely, we might turn to the use of copper sulphate to kill the germ, and be justified in so doing, because of its occasional appearance; but in dealing with typhoid fever and the general sewage question, we would be forced to apply the remedy day in and day out for a long period of time, indeed, permanently.

And again, what do we accomplish by such use, even supposing that the salt be not poisonous? What do we accomplish in the way of the reduction of turbidity, in the way of taking out the color, in the way of improving the physical appearance of the water? If our water be such that its appearance needs improving, why, the very means that we use to accomplish that result, namely, the modern filtration plant, will, of itself, remove the germs that we are anxious to get rid of without any necessity of killing the same by the addition of copper sulphate.

I very much question whether we know all that may be known with reference to the poisoning effect of copper sulphate upon the human economy. We are limited to a consideration of the effect of occasional and relatively large doses. The question here is, What would be the result should we feed our people small amounts of copper sulphate during long periods of time? That inquiry has to be, I think, still left unanswered.

I am looking forward with a great deal of pleasure to listening to what may be said during this discussion. There was one point in Dr. Moore's remarks that seemed to me especially worthy of being touched upon, namely, the resistant strain of aquatic life

about which he spoke; the suggestion that the material with which he experimented in the laboratory was possibly a little more resistant than the material as it would be found in practice. With reference to algal growths I have nothing to say, being in ignorance on the point, but as touching pathogenic germs, I have strong doubts about those of the laboratory being as resistant as the ones fresh from the excreta. It may be that there are those who will assist us to further information upon that point to-day, but it would not surprise me very greatly to find that the dose of copper sulphate which would kill the laboratory bacillus would fail to do as much for his wilder brother of the bowel.

Destruction by Copper Sulphate of Typhoid Fever Germs.

BY DANIEL D. JACKSON, MT. PROSPECT LABORATORY, BROOKLYN, N.Y.

The destruction of the germs of typhoid fever in water by means of copper sulphate has been the subject of a considerable amount of discussion during the present year, and no definite decision has been heretofore reached as to the amount of copper sulphate required for this purpose. The differences of opinion on this subject have undoubtedly been largely due to differences in the virulence of the cultures employed. The ordinary laboratory cultures which have been resuscitated by growing in beef broth have been supposed to regain their original virulence, but the experiments which are cited in this paper show that such is by no means the case, and that the highest degree of virulence is only obtained when the typhoid culture is taken fresh from the human subject directly after death.

Resuscitated typhoid cultures obtained from several prominent laboratories were experimented upon to determine the amount of copper sulphate required to destroy them. The following table gives the results obtained when the cultures were treated in distilled water with various amounts of copper sulphate:

TREATMENT OF ORDINARY TYPHOID BACTERIA IN DISTILLED WATER WITH COPPER SULPHATE.

Amount of Copper Sulphate Used.	Number of Typhoid Bacteria Remaining after 3 Hours.	after 24 Hours.
None	1 980	1 200
1–20 000 000	1 920	1 100
1–10 000 000	1 180	420
1– 5 000 000	980	265
1– 3 000 000	435	3
1– 2 000 000	0	0
1– 1 000 000	0	0
1– 500 000	0	0

It will be seen from this table that the amount required for the sterilization of such a culture is one part of copper sulphate in two million parts of water.

The table which follows shows the same treatment as in the previous table, except that sterilized Brooklyn tap water was used:

TREATMENT OF ORDINARY TYPHOID BACTERIA IN STERILIZED BROOKLYN TAP WATER WITH COPPER SULPHATE.

Amount of Copper Sulphate.	Number of Typhoid Bacteria Remaining after 3 Hours.	after 24 Hours.
None	2 300	1 640
1–20 000 000	1 450	830
1–10 000 000	1 320	120
1– 5 000 000	570	80
1– 3 000 000	120	5
1– 2 000 000	0	0
1– 1 000 000	0	0
1– 500 000	0	0

It will be seen that in both of these cases one part of copper sulphate in two million parts of water is sufficient for disinfection.

These two experiments are representative of a very considerable number of others along the same lines, but from the next table it will be seen that the results are very different from those obtained when fresh, virulent typhoid bacteria are used.

TREATMENT OF VIRULENT TYPHOID BACTERIA IN STERILIZED BROOKLYN TAP WATER WITH COPPER SULPHATE.

Amount of Copper Sulphate Used.	Number of Typhoid Bacteria Remaining after 3 Hours.	after 24 Hours.
None	82 000	68 000
1–3 000 000	23 000	12 300
1–2 000 000	18 400	1 300
1–1 000 000	12 800	450
1– 500 000	560	23
1– 100 000	8	2
1– 50 000	0	0

It is evident from the above figures that typhoid bacteria of the attenuation usually found in water are destroyed by copper sulphate in the proportion of one part to two million parts of water. These results, however, are not obtained when fresh, virulent typhoid germs occur in water. A strength of one part copper sulphate to fifty thousand parts of water is then required. It is, however, entirely impracticable and unsafe to use such a strength in the treatment of drinking water, as an amount greater than one part per million can be detected by taste, and if taken constantly would be likely to produce a physiological effect upon the consumer.

Very considerable light is shed upon the subject of typhoid treatment by experimenting upon the *bacillus coli communis*. This bacterium is present under normal conditions in the human intestine and is very closely comparable with the typhoid bacterium in respect to its behavior with antiseptics.

After having obtained very similar results upon the *bacillus coli* by the use of copper sulphate, an experiment was made upon a water supply pond in the borough of Brooklyn containing sixty millions gallons of water. The water of this pond is used only after mechanical filtration, and under such circumstances all copper has been found to be removed. The accompanying diagram, Fig. 1, shows the removal of *bacillus coli* from the pond by means of a treatment of one part copper sulphate to two million parts of water. The lower portion of the chart shows the positive presumptive tests for *bacillus coli* obtained in dilutions of 0.1 cc.,

1 cc., and 10 cc. The middle line shows the total amount of gas obtained in the three presumptive tests for each day, and the top line shows the total number of bacteria present throughout the experiment. The results show that *bacillus coli* of the attenuation found in water is (until receiving further contamination) completely removed by a treatment of copper sulphate in the proportion of one part to two million parts of water.

Little or no effect is produced upon the common bacteria in water by such a strength of copper sulphate, and unless the copper

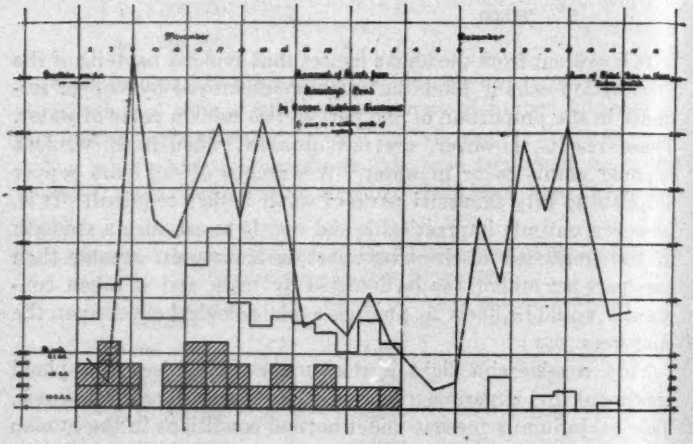


FIG. 1.

is rapidly removed by precipitation the common bacteria usually increase enormously in numbers, especially when a considerable amount of food has been rendered available by the killing off of large numbers of algæ by means of the copper treatment.

In cases of epidemic from typhoid fever in a water supply, the disease bacteria may be greatly attenuated and rendered much less dangerous by a treatment of one part copper sulphate to one million parts of water. It is probable that this treatment will kill off all typhoid germs of the usual attenuation found in water, but at no time should more than this strength be used.

The Use of Metallic Copper for the Purification of Drinking Water.

BY PROF. HENRY KRAEMER, PHILADELPHIA.

Before giving the results of my experiments with copper foil in destroying certain intestinal organisms, I desire to give some general observations with regard to the use of copper in the purification of water supplies, as the subject presents itself to me.

What I wish to bring out is that there appear to be distinct uses for copper foil and for copper sulphate or the salts of copper, and also that there is a proper time and place for the use of these.

Copper foil seems better adapted for use in the average household, and may be used when the drinking water supplied to a community is a diluted sewage, as it is in a number of places.

Salts of copper seem better adapted for disinfecting the discharges of typhoid patients, treatment of sewage, and the purification of contaminated water in reservoirs.

Theoretically, there should be no need of treating either the water in a reservoir (except where there is algal growth) or that which is supplied the householder from the city supply, except when there is contamination as a result of accident, as sometimes happens, granting that the sources of contamination have been properly safeguarded.

The discharges from typhoid patients being the source of the disease, it is obvious that the disinfection with copper sulphate should begin here, and physicians should give instructions accordingly. If universal attention were given to this matter there can be little doubt that the spread of typhoid fever would be prevented almost entirely. But as the matter cannot be absolutely controlled the next best thing is to *disinfect the sewage.*

That certain organisms manifest a specific sensitiveness towards copper was first pointed out by Naegeli. Following the lead of Naegeli, Israel and Klingmann (1897) showed that copper foil has a marked toxic effect on certain bacteria, as *bacillus coli* and the organisms producing typhoid fever and cholera. To Moore and Kellerman (1904) belongs the credit of first showing the application of the results obtained by Naegeli (on algæ) and Israel and Klingmann (on bacteria) in the purification of water supplies.

As the methods used in my work have been published and are readily accessible, it will probably be sufficient to call attention to some of the main features of the work.

1. The copper used was in the form of sheet copper or copper foil, pieces approximately 9 cm. square being used to each 1 000 cc. of water.

2. The organisms upon which we experimented were *bacillus coli* and *bacillus typhi*, twenty-four-hour bouillon cultures being used.

3. The water used in the experiments included filtered, distilled, and tap water, all of which were sterilized in an autoclave prior to adding the cultures and copper foil.

We found in nearly every experiment which we conducted that in the water containing the typhoid or colon organisms, and to which the copper foil was added, these organisms were destroyed in from two to four hours.

We also found in the parallel experiments which we conducted that in the water to which copper foil was not added, the typhoid and colon bacilli continued to grow and even multiply for months, except in the case of water filtered by means of a filter attached to an ordinary copper faucet. In the latter instance the typhoid organisms were destroyed in two to four hours, just as though copper had been added to the water, whereas the colon bacilli continued to grow, but not as rapidly as in distilled or tap water. This peculiar inhibiting action of the filtered water we subsequently proved was due to a property acquired by the water in its slow passage through the copper spigot to which the filter was attached. That the inhibiting action of the filtered water was due to its contact with the copper spigot, is shown by the fact that when we used a filter in which contact with copper was avoided, the typhoid organisms continued to grow the same as in distilled and tap water.

Later experiments showed that contact of the copper foil with the water for a very brief period of time was sufficient to affect these organisms. We found, for instance, that if the copper foil were allowed to remain in distilled water for one to five minutes, the typhoid organisms were completely destroyed within a few hours.

In a paper presented to the American Philosophical Society, the results of my work along this line are summarized as follows:

Certain intestinal bacteria like colon and typhoid are completely destroyed by placing clean copper foil in water containing them, or by adding the organisms to water previously in contact with copper foil.

The toxicity of water to which either copper coins or copper foil has been added is probably due to a solution of some salt of copper, as first suggested by Naegeli.

The copper is probably in the form of a crystalloid rather than that of a colloid, as it has the property of permeating the cell walls and organized cell contents of both animals and plants, thereby producing the toxic effects.

While the effects produced by the oligodynamic action of copper are apparently different from those of true chemical poisons, the difference is probably in degree only and not in kind.

Certain lower organisms, including both plants and animals, possess a specific sensitiveness to minute quantities of copper, and it has been shown that they are not restored on transferring them to water free from oligodynamic properties.

Oligodynamic solutions of copper are obtained by adding either copper coins, copper foil, or salts of copper to water; when copper foil is used, sufficient copper is dissolved by the distilled water in one to five minutes to kill the typhoid organisms within two hours.

A solution of copper may lose its toxicity by the precipitation of the copper as an *insoluble salt* or *compound;* by its *absorption* by *organic substances;* or by *absorption* by *insoluble substances.*

The oligodynamic action of the copper is dependent upon temperature, as first pointed out by Israel and Klingmann.

The effects of oligodynamic copper in the purification of drinking water are in a quantitative sense much like those of filtration, only the organisms removed, like *bacillus typhi* and *bacillus coli*, are completely destroyed.

THE EFFECTS OF WATER TREATED WITH COPPER ON MAN.

While it has been conclusively shown that exceedingly minute quantities of copper are toxic to typhoid organisms, still the question is raised by some as to the toxic effects on man when copper or its salts are used in the purification of drinking water.

In commenting on a paper of mine on "The Efficiency of Copper Foil in Destroying Typhoid and Colon Bacilli in Water," a reviewer writes as follows: "While recommending the use of copper foil for the purification of drinking water, the writer adduces no proofs as to freedom from toxic effects when water so purified is taken into the system over a considerable period of time." My reason for not taking up the pharmacological phase of this question heretofore has been that my own experiments in the consumption of water treated with copper foil did not extend over a sufficient period of time to warrant me in making any statements in regard to the effects of water so treated. Then, too, I felt that the statements of pharmacologists and physiologists were conclusive as to the probable harmlessness to man of copper when used in the proportions necessary to purify water containing typhoid organisms. But since there seems to be some objection in certain communities to the drinking of water treated with copper, I have deemed it advisable to give my own experience in connection with this subject.

For nearly a year all of the drinking water consumed in my home has been treated with copper. A strip of copper foil, or sheet copper, nine inches square, is placed in a vessel containing from three to four quarts of water and allowed to remain from four to eight hours. The foil is first cleaned with powdered pumice, and retains its luster for weeks unless the water contains a considerable quantity of sediment, and provided the quantity of water is renewed immediately each time upon drawing off the sterilized or purified water. On account of the varying amounts of sediment, we find it desirable to filter the water before treating it with copper foil. Up to this time no ill effects have been noted from drinking the water so treated, and, in fact, our general health may perhaps be said to be better than usual, in that we have not had to consult a physician during this time. Another interesting observation is that the water being more palatable than boiled water, we consume larger quantities, which possibly has some influence on the general bodily condition.

Believing that many vegetables may also be a source of infection, we take the precaution either to wash the vegetables to be eaten raw with copper-treated water, or to place them, particularly

in the case of lettuce and celery, in a vessel of water along with a strip of clean copper foil and allow them to remain from two to four hours with occasional agitation.

The use of copper vessels would be more convenient, but of course is more expensive. I have also thought that water pitchers and tumblers might be partly lined with copper foil.

From my own experience and observations, together with those of others, we may draw certain general conclusions, which I have summarized as follows:

It is pretty well established that the typhoid organism is disseminated not only through water, but also through air and food, and may retain its vitality for a considerable period of time.

Typhoid organisms in water are eliminated by filtration, boiling, and by certain biochemical methods. Of the latter, the use of copper, as proposed by Moore and Kellerman, is probably the most efficient and at the same time the most practicable.

While exceedingly minute quantities of copper in solution are toxic to certain unicellular organisms, as bacteria, it is safe to assume that the higher plants and animals, including man, are unaffected by solutions containing the same, or even larger amounts of copper.

There being a number of factors which tend to eliminate the copper in solution, it is hardly likely that there would be any copper in solution by the time the water from a reservoir reached the consumer if the treatment of the reservoir were in competent hands.

Many plants contain relatively large quantities of copper, and when these are used as food, some of the copper is taken up by the animal organism, but there are no records of any ill effects from copper so consumed.

The Toxicology of Copper and Its Relation to the Copper Treatment of Water.

BY HERBERT E. SMITH, M.D.*

So firmly imbedded in the popular mind is a belief in the poisonous action of copper, that the question of the toxicology of copper

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is one that presses for an answer wherever it is known that copper sulphate is to be used in a public drinking water. There are generally objections to a chemical treatment of drinking water, but because of the common belief, people may justly demand a positive answer to the question, — Is the use of copper in our drinking water likely to be injurious?

If I should attempt to give a review of the literature of the toxicology of copper, I should have to present a wearisome mass of conflicting opinion and statements of alleged facts, which would but end in confusion. Therefore, I will confine myself to a brief statement of the matter as it appears from the experimental work and observations of the past few years.

In order to understand the toxicology of copper, one must distinguish sharply on the one hand between the irritant action which copper salts produce on the mucous membranes of the stomach and intestines when they are swallowed, and on the other hand, the effect which they produce upon the cells of the interior organs of the body after they have been absorbed into the blood.

The first effect is that which would be produced on man by the ingestion of a large dose, *i. e.*, several grams of copper sulphate, and would be manifested by nausea, vomiting, colic, diarrhea, and the other symptoms of a gastro-enteritis. These are the symptoms most commonly seen in copper poisoning in man, and usually constitute about all there is in an attack of this sort, for rarely does it happen that acute systemic poisoning occurs in man.

That copper is capable of producing profound systemic poisoning, however, is abundantly shown by the laboratory experiments of Tschisch, Lehmann, Filehne, and others, in which the copper compounds were introduced by the hypodermic method into rabbits, cats, and dogs. The symptoms produced in this way are referable to the direct action of the poison on the protoplasmic contents of the cells in the various organs affected. The chief symptoms are muscular paralysis, jaundice and other signs of fatty degeneration of the liver, hematuria and other signs of an acute toxic nephritis, destruction of blood corpuscles, and usually disturbance of the functions of the alimentary canal. Death usually occurs as the result of cardiac and respiratory paralysis.

Systemic poisoning *may* be caused by absorption from the

alimentary canal, as has been shown by experiments on sheep and other animals that do not vomit. It appears, however, that the dose must be large enough to produce gastro-enteric disturbances. It is, therefore, possible to get both the irritant and the systemic effects by repeated administration of moderately large doses.

With lead and mercury, repeated small doses produce severe systemic poisoning; this appears not to be the case with copper.

Kunkel, who has written perhaps the best modern systematic toxicology, says that chronic poisoning with copper, in the sense that we have it with lead and mercury and in which it has been claimed for copper, does not exist; that is, the administration of small quantities of copper continued through a long time does not produce deleterious results.

It is true that one may find in medical literature some cases described as chronic copper poisoning, but such are admittedly rare, and on close analysis appear to be of mistaken diagnosis.

In the support of the statement that copper does not produce chronic poisoning may be advanced the numerous experiments on man himself. Thus one observer took from ten to twenty milligrams of copper in the form of copper sulphate daily for eighty days and another for fifty days, with no ill effect. Doses of over sixty milligrams, however, produce some alimentary disturbance and would doubtless prove injurious if long continued. The form in which copper is taken has much to do with its effect. The simple salts like the sulphate and acetate are most active, while the compounds formed between copper and albumins are much less active.

The conclusions then which may be deduced from the recent literature are, that a single large dose of a salt of copper may produce in man acute irritant poisoning, followed sometimes by systemic poisoning; that repeated moderate doses produce a subacute poisoning, due largely to the systemic effect; and that repeated small doses, say from ten to thirty milligrams administered by the mouth, cause no poisoning even when continued many days.

The question before us, therefore, turns largely on the dose, and on the form and manner of ingestion. For the purpose of

obtaining a probable dose which might result from the use of copper sulphate in a reservoir, let us assume the use of one part of copper sulphate per million of water. This means that one kilogram of water would contain one milligram of copper sulphate, or about one quarter of a milligram of metallic copper. An assumption of a daily maximum use of two kilograms of water, something more than two quarts, would give a daily dose of one half a milligram (0.5 mgm.) of copper, or about one one hundred thirtieth part of a grain. This is a quantity which when administered by the mouth must be regarded as insignificant as a toxic agent on man, and would be so even if increased several fold. Ordinary precaution on the part of the operator would induce him to avoid a concentrated solution in the vicinity of a water intake, so that this danger of a possible larger dose is no necessary feature of the application of the method.

I have assumed that the copper was in solution as sulphate in the water, but experience teaches that the copper rapidly disappears from solution after the treatment. This means, of course, that the copper is precipitated in some form, and the question may arise as to the danger from concentration of the copper in the form of sediment. This is a possibility and therefore the form in which the copper is precipitated is of importance. It seems probable that the copper is precipitated in albuminous combinations, that is, that it is absorbed by the albuminous constituents of the microscopic organisms in the water. The basis for this suggestion may be deduced from the following considerations. The most delicate tests which the chemist has for the detection of copper are hydrogen sulphide and potassium ferrocyanide. The limit of delicacy of these reagents is given by Professor Wormley as about one part of copper oxide in one hundred thousand parts of solution. The only precipitants uniformly present in natural water are the alkalies, and surely they could not precipitate the copper from a solution of one part per million, for they are much less delicate than the reagents mentioned. But suspended albuminous matter might absorb it, and that this action does take place is indicated by the fact that the dead organisms collected in reservoirs after the treatment, have been found to contain considerable quantities of copper. This method of

precipitation is important because these albuminous compounds have been found to be of low toxic power, and, therefore, do not materially increase the danger of poisoning to those using the water.

Support of the assertion that such small amounts of copper as are involved in reservoir treatments are not toxic, may be drawn from the common use of articles of food containing relatively larger quantities of copper. Thus grain and vegetables grown in copper-containing soils are found to contain notable quantities of this metal. Wheat has been found to contain from three to ten milligrams of copper per kilo, and various green vegetables from three to twenty milligrams. Canned vegetables, especially peas, are frequently treated with copper sulphate to preserve their green color. From twenty to thirty milligrams per kilo are common amounts, and frequently much more has been found, yet such materials have been widely used without deleterious effect. Copper is also frequently introduced into food through the use of copper and brass utensils. Indeed, so commonly are articles of food contaminated with copper that Gautier has estimated that from four to five milligrams of metallic copper are ingested daily by most men in their food.

From all of these considerations, one may conclude that there is no danger to the public health from the use of copper sulphate in drinking waters as it is applied for ridding them of the various microscopic algæ.

There are one or two other thoughts which occur to me. First, why is it that if copper is so poisonous to man and the lower animals when injected into the blood, small quantities taken into the stomach do not have any deleterious effect? I believe it is merely a question of absorption. If injected into the blood small quantities of copper are poisonous to mammals and doubtless to man. If taken into the stomach, however, the system is protected by the albuminous constituents of the blood and by the albuminous envelopes through which the copper must pass before it gets into the blood. That is the explanation and the only one I can see why copper in small doses is not poisonous to man — it does not get where the poisonous effect can be produced.

Why is it, if copper in these very small quantities is not poison-

ous to man, that it is so highly poisonous to organisms which we find in water? Why is it that uroglena will succumb even to one part of metallic copper in sixty, seventy, or eighty million parts of water, as I have seen it in actual experiments? It must be wholly a question of the way in which the copper can get at the organism. I cannot conceive that the protoplasmic material of uroglena is substantially different from that of many other related forms; but I can conceive that there is a difference in the ease with which the copper can penetrate to the cell, and I believe we shall find that that is the main reason why we have the selective difference which has been referred to.

The question of fish is one which I am not quite ready to deal with. I do not see why there should be such a marked difference as has been referred to in the susceptibility of different fish. I do believe that fish are more susceptible to copper than most other animals, and they have been proved to be by experiments, because fish have a better opportunity to absorb it than other animals. They have a very good absorbing apparatus in their gills, and I have sometimes thought they might get the copper in that way in very much larger quantities; but why the pickerel should have so much more selective action than the black bass I can see no present explanation for.

Behavior and Uses of Copper Sulphate in the Purification of Hard and Turbid Waters.

BY JOSEPH W. ELLMS, CINCINNATI, OHIO.

The proposed general use of copper sulphate in connection with the filtration of public water supplies, in order to further safeguard the purity of the effluent through the germicidal properties of this compound, immediately raises the question as to the character of the chemical reactions which occur when copper sulphate is introduced into a natural water. In the filtration of waters through slow sand filters without the use of chemical coagulating compounds, the applied copper sulphate would react with the natural constituents of the water; but in the case of waters coagulated and filtered with the assistance of chemicals, the latter would

also enter into the changes which would take place. From a few experiments made by the writer the general character of these reactions appeared to be as follows:

The bicarbonates of lime and magnesia naturally present in most waters are the compounds which give to them their temporary hardness. It is with these salts that the copper sulphate reacts. Since no neutral carbonate of copper is known, the probability is, that a basic carbonate of copper is first formed, which may gradually break up into an insoluble cupric hydrate and free carbonic acid. The reactions which take place may be represented as follows:

(1) $2\,CuSO_4 + 2\,CaH_2(CO_3)_2 = CuCO_3.CuO_2H_2 + 2\,CaSO_4 + 3\,CO_2 + H_2O.$
Copper sulphate + Bicarbonate lime = Basic carb. copper + Calcium sulphate + Carb. acid + Water

The basic carbonate of copper may possibly decompose according to reaction (2).

(2) $CuCO_3.CuO_2H_2 + H_2O = 2\,CuO_2H_2 + CO_2.$
Basic carb. copper + Water = Copper hydrate + Carbonic acid

The hydrate of copper is said to be an insoluble compound. The basic carbonate of copper is more or less soluble in water containing carbonic acid.*

The experiments made appeared confirmatory of the general character of the reactions as outlined above. The precipitate was colloidal in character, separating slowly and imperfectly from the water. About 40 or 50 per cent. of the copper sulphate applied to the water could be detected in solution if the treated water was filtered within ten or fifteen minutes after applying the chemical. If three hours elapsed, however, before filtering, from 70 to 95 per cent. of the copper was removed, and at the end of twenty-four hours no copper could usually be detected in the filtered water by the colorimetric test employed.

These results seem to indicate, that either a slow deposition of the basic carbonate of copper from its supersaturated solution

* Comey's Dictionary of Chemical Solubilities.

was taking place, or that it was being converted from a soluble form due to the free carbonic acid present in the water, into an insoluble hydrate of copper. Whether the basic carbonate of copper or the hydrate is the end product of the reaction is somewhat uncertain from the evidence obtained. Practically it is of no material importance. The point to be noted is, that it was plainly evident that the copper compound first formed was soluble to a certain extent, and that its solubility slowly diminished as more time elapsed, and finally it was practically all precipitated.

Other experiments appeared to indicate that the solubility and non-precipitation of the applied copper was largely due to the free carbonic acid either naturally present in the water or liberated by the mutual decomposition of the copper sulphate and calcium and magnesium carbonates. By adding caustic lime to the water after introducing the copper sulphate, in order to combine with all of the free and half-bound carbonic acid in solution, all of the copper was very soon precipitated, and none was found in the filtered sample. If, however, all of the free and half-bound carbonic acid was not removed by caustic lime, then only a portion of the copper was immediately precipitated; although after three hours had elapsed the whole of the copper appeared to have passed out of solution. For example, when no lime was used, only 50 per cent. of the applied copper was removed within ten or fifteen minutes after treatment; when a reduction of 23 per cent. in the free and half-bound carbonic acid was effected with caustic lime, 88 per cent. of the copper was removed; and when 100 per cent. of the free and half-bound carbonic acid was eliminated, no copper was detected in the filtered sample. When 44 per cent. of the free and half-bound carbonic acid had been removed from a water in another experiment and the water allowed to stand for three hours, all of the copper was found to have passed out of solution.

One can readily enough conceive of a direct reaction occurring between the basic carbonate of copper and the caustic lime added as follows:

$$CuCO_3.CuO_2H_2 + CaO_2H_2 = 2\,CuO_2H_2 + CaCO_3.$$

In this case we have the basic carbonate of copper converted into the insoluble hydrate.

The influence of organic matter in preventing the precipitation of copper is well known. A few experiments were made by the writer in which a hard water was artificially colored, in one case with a caramel solution and in another with a leaf infusion, in order to imitate a natural colored water. In both experiments only 70 per cent. of the applied copper sulphate was precipitated in three hours time, whereas in the same water without the coloring matter 90 per cent. of the copper was precipitated. The residual amount of copper sulphate in each of the "colored water" experiments was between seven and eight parts per million. In another experiment in which ten parts per million of copper sulphate had been added to a hard water colored with a leaf infusion, five parts per million were found at the end of sixteen days. This indicates a reduction of only 50 per cent. of the amount of copper sulphate applied. It would appear from these results that the quantity of copper held in solution by organic matter may vary, and that quantities as great as five parts per million may be retained in solution for long periods of time.

It was further found that by adding caustic lime to the water in sufficient amount, practically all of the copper was precipitated. In an experiment where 44 per cent. of the free and half-bound carbonic acid had been removed by caustic lime, no copper could be detected in the filtered sample. In another experiment where the copper sulphate had been in solution in a colored water for over two weeks, an addition of caustic lime at the end of this period to remove a portion of the free and half-bound carbonic acid did not appear to entirely remove the copper. Probably where a complex stable compound has been formed between the copper sulphate and the organic coloring matter, it would be necessary to render the water slightly caustic in order to decompose the copper compound and cause its precipitation.

So far as these few experiments indicate conditions which may exist in natural waters when treated with copper sulphate on a large scale, the following conclusions may be drawn:

1. That copper sulphate applied to a water having bicarbonates of lime and magnesia in solution, reacts with these salts to produce a compound which is at first partially soluble in the water, and which only slowly becomes insoluble and passes out of solution.

2. That probably within twenty-four hours all of the copper sulphate applied to a hard water having practically no organic coloring matter and containing but little free carbonic acid, is converted into an insoluble form and can be filtered out.

3. That organic coloring matter tends to retain a portion of the copper and to prevent its precipitation, and that its complete elimination is not effected for a considerable period of time.

4. That by the use of enough caustic lime to remove the free and half-bound carbonic acid, the applied copper sulphate can be rendered insoluble in hard waters containing little organic matter, and that colored waters may require an excess of lime so that the water is caustic in order to remove all of the copper.

5. That the colloidal character of the precipitated copper compounds renders them difficult to remove by sedimentation alone, and that the filtration of the water is probably necessary for their complete and rapid removal.

There is as yet comparatively little information available in connection with the use of copper sulphate in filtration, from which conclusive evidence as to its efficiency as a bactericidal agent can be drawn. The evidence at hand, however, appears to indicate that we have in this compound a valuable aid to the purification of polluted waters. There are one or two points in connection with its use in filtration which may be profitably discussed in the light of the few data available. In the first place it must be conceded that copper sulphate in sufficient quantity will destroy certain disease-producing bacteria, such as the bacilli of typhoid fever and cholera. It will also kill the intestinal bacillus *B. coli communis;* but that it has any selective action in removing from water any of the above organisms in preference to the ordinary water bacteria, as has been suggested, the writer does not believe is sufficiently well proven. When copper sulphate is applied to a water containing only the common water bacteria, it would naturally exert its greatest destructive action upon the weaker individuals. The disease-producing germs being in an unnatural environment when in water, are probably the first to succumb to the toxic action of the copper sulphate on account of their debilitated condition. But it seems just as likely that the weaker water bacteria are also destroyed at the same time,

leaving only the hardier individuals. The toxic effect of the copper is thus probably selective only in the sense of its being more destructive of the weaker organisms. This appears to be the only rational explanation for certain results observed in recent tests of two municipal filtration plants where copper sulphate was used, and at which the writer was present.

The amounts of copper sulphate which a number of experimenters have reported as necessary to destroy such bacterial forms as *B. coli* and *B. typhi*, are so much larger than those reported by other investigators and so much greater than appeared effective in the tests of the municipal filtration plants referred to above, that some explanation seems necessary. As pointed out by Moore and Kellerman,* the conditions under which earlier investigators carried on their experiments were far different from those existing in most public water supplies. The more recent experiments appear to indicate that quantities of copper sulphate ranging from two to ten parts per million of water are toxic to pathogenic or allied forms. The presence of much organic matter undoubtedly retards, if it does not even prevent, the action of the copper compounds on the bacteria, and thus requires a larger quantity of copper to be used than that cited above to produce the desired results. The length of time required for contact of the organisms with copper compounds in order to destroy them, appears also to be variable. The factors influencing the quantity of copper sulphate necessary to destroy bacteria, therefore, are so variable that only within rather wide limits can the amount which would be toxic to any particular organism, be stated.

When a water which has been treated with copper sulphate is filtered through a sand filter, the insoluble copper which has not settled out in preliminary settling basins, passes on to the sand bed and is deposited. It is evident that the longer the filter is in operation the greater becomes the quantity of copper deposited on the surface of the sand bed. It is through this deposit of copper that all the water is passing which is being filtered. The deposited copper thus forms a danger zone through which all the bacteria coming upon the bed must pass. Even though the original concentration of the applied copper sulphate may be very small, the

* Bulletin No. 64, page 29, U. S. Dept. Agriculture.

continuous deposition of insoluble copper compounds going on at the surface of the sand has virtually the effect of a continually increasing concentration.

The efficiency of the copper sulphate depends not only upon the condition of the organism and the character of the water in which they are disseminated, but on the opportunity afforded for the coming together of the organism and the toxic copper compounds. It, therefore, seems very reasonable to expect that water treated with relatively minute quantities of copper sulphate will be effective when the water is subsequently filtered, because the sand bed offers not only a chance for increasing quantities of copper to be deposited, but affords a place where actual contact between the organism and the toxic copper compounds can take place.

The copper compounds precipitated are probably always colloidal in character. It has been pointed out recently by one investigator,* that in this form it has a more rapid toxic effect on typhoid organisms than on the ordinary water bacteria. The precipitation of the copper in the colloidal form is for some reasons unfortunate, since in this condition it settles out very slowly and imperfectly. This property renders it much more difficult to eliminate from a water which is not subsequently filtered; and it can be readily understood that in the case of a water carrying considerable organic matter, traces of copper might be retained for a long period of time. It is not the writer's belief, however, that these traces would be in the least harmful to persons drinking the water.

The use of copper sulphate with chemical coagulating compounds somewhat complicates the problem of its final disposal. If sulphate of alumina is used with copper sulphate the increased quantity of carbonic acid produced by the mutual decomposition of the sulphate of alumina and bicarbonates of calcium and magnesium would have a retarding action on the precipitation of the copper. Where caustic lime and sulphate of iron are employed as coagulants, the former by removing the carbonic acid would tend to aid the precipitation of the copper. As was indicated by

* "A Study of the Action of Colloidal Solutions of Copper upon Bacillus Typhosus," by A. H. Stewart, Am. J. Med. Sci., 129, 760–769.

the experiments recorded in the first portion of this paper, the addition of lime also assisted in hastening the removal of the applied copper. The introduction of lime, therefore, affords a means of eliminating copper from soft waters and from colored waters and thereby renders its use in slow sand filters a possibility.*

While the evidence in regard to the value of the use of small quantities of copper sulphate for its bactericidal effect in connection with filtration is limited, still that which has been produced is worthy of careful consideration. A thorough scientific investigation of the whole question, undertaken on a large scale, is especially desirable in so far as it relates to water purification, in order that we may know the advantages as well as the disadvantages which result from its employment as a disinfectant of public water supplies.

The Use of Copper Sulphate in Water Filtration.

BY H. W. CLARK, CHEMIST, STATE BOARD OF HEALTH, BOSTON, MASS.

An experiment was begun at the Lawrence Experiment Station in May, 1904, in order to test the value of copper sulphate as an aid in the purification of polluted water. In this investigation a large experimental filter, 17 feet 4 inches in diameter and containing 2½ feet in depth of good filter sand, was used. Before the beginning of the copper sulphate experiment, this filter had been in use for eleven years, filtering Merrimac River water. Beginning May 17, 1904, however, copper sulphate was added to the raw water applied to this filter, the amount used at first being 1 part of the sulphate in 1 000 000 parts of water, and the greatest amount used during the year of experiment was 1 part in 133 000 parts of water.

The copper sulphate was applied directly to the water upon the surface of the filter, but the volume of water always above the sand allowed a storage of water, after introduction of the sulphate, ranging from five and one-fourth hours to slightly more than eight

* This fact was pointed out by Moore and Kellerman in Bulletin No. 64, U. S. Dept. Agriculture.

hours, varying, of course, with the rate of filtration at which the filter was being worked.

Examination of the sand of the filter from time to time during the experiment and after the experiment had ended, showed the accumulation of a large amount of copper in the sand, and also showed that the copper penetrated the entire depth of the filter. At the end of the experiment, the amount of copper in the surface sand of the filter was 22.8 parts per 100 000; at a depth of 12 inches, 7.6 parts per 100 000; and at a depth of 24 inches, 6.8 parts per 100 000. Giving these results in terms of copper sulphate, the surface sand contained 89.5 parts of copper sulphate per 100 000; at 12 inches there were 79.8 parts present, and at 24 inches there were 26.6 parts present.

Analyses of the effluent of the filter showed that this effluent contained copper, calculated as copper sulphate, varying in amounts at different times from 1.2 parts per million parts of water to 5.8 parts per million parts of water. At the end of August, 1905, three months after we had ceased to add copper sulphate to the applied water, the effluent contained copper, calculated as copper sulphate, to the amount of 3.7 parts per million parts of water, showing that copper was continually being taken into solution from the deposit within the filter.

The actual volume of water passed through this filter daily varied from 14 000 to 26 000 gallons, and the rate of filtration varied from 2 800 000 to 4 700 000 gallons per acre daily.

In connection with this work, experiments were made in regard to the rate of sedimentation of copper sulphate after being mixed with water in large tanks at the Experiment Station, using, of course, water of the same character as that used in the filtration experiment; and in one of these sedimentation experiments it was found that there was practically no sedimentation of the copper until after a period of twenty days; in one, a reduction of 50 per cent. in fifty-four days; in one, a reduction of about 60 per cent. in sixty-two days; and in one, a reduction of 58 per cent. in twenty-one days. No sedimentation occurred in periods of twenty-four or forty-eight hours.

If, therefore, in this filtration experiment, a sedimentation tank had been placed between the point of application of the copper

sulphate and the filter, a normal period of sedimentation would have effected little copper removal, and practically all the copper not passing through the filter and appearing in the effluent would have collected upon the filtering material.

During the entire period of this investigation, samples of the water passing to the filter and the effluent of the filter were taken daily for bacterial examination. The bacterial results obtained from the filter during this experiment when compared with those obtained during the year previous to the application of copper sulphate to the raw water, show no gain in bacterial removal on account of the use of the copper sulphate, but rather the reverse. During the year previous to the use of copper sulphate, the raw water contained 8 300 bacteria per cubic centimeter and the effluent, 73 bacteria per cubic centimeter — or a bacterial efficiency of 99.12 per cent. During the year of copper sulphate treatment, the raw water contained 7 400 bacteria per cubic centimeter and the effluent of the filter, 114 per cubic centimeter — a bacterial efficiency of 98.5 per cent., 0.62 of one per cent. less than during the previous year. During both years practically every cubic centimeter sample of the raw water that was tested contained *bacillus coli*. The effluent of the filter during the year before the copper treatment contained *bacillus coli* in 13.5 per cent. of the cubic centimeter samples examined, and during the year of copper treatment it was found in 26 per cent. of the cubic centimeter samples examined; samples, of course, being taken daily. Besides the poorer bacterial results obtained, the filter was less efficient in producing an effluent free from organic matter.

Summarizing, it can be said that poorer results in water filtration were obtained when using copper sulphate than when operating the same filter without the use of the copper sulphate; a poorer effluent, organically, was obtained, and there was an accumulation of copper upon the sand in the filter that would eventually — if copper, in the form in which it remains upon the sand, has any strength at all as a bactericide — reduce the efficiency of the filter very greatly; that is, the biological actions upon which good results with slow sand filters depend would be badly impaired.

The Use of Copper Sulphate for Reducing the Pathogenicity of Sewage and Sewage Effluents.

BY GEORGE A. JOHNSON, ENGINEER IN CHARGE, SEWAGE TESTING STATION, COLUMBUS, OHIO.

There are two ways in which the sewage of large communities is disposed of at the present time. Briefly, these methods may be referred to as: First, by dilution, that is, by the dispersion of the sewage in its raw state in large bodies of water; and second, by artificial methods of purification, especially filtration, and the subsequent dispersion of the effluent in water.

Current methods for the artificial purification of sewage may be divided for present purposes into two classes wherein fine-grain and coarse-grain filtering materials, respectively, are made use of. The former processes embrace broad irrigation fields, or more limited sandy areas of selected soil, while the latter processes include the contact filter and sprinkling filter, both of which have been developed during the past ten years. The fine-grain filters yield effluents of a materially higher grade of purity than do those composed of coarse-grain material. In a general way, the former processes may ordinarily be expected under favorable conditions to remove upwards of 99 per cent. of the bacteria contained in the sewage. The coarse-grain filters, on the other hand, which are especially serviceable in making sewage non-putrescible, will remove perhaps in the neighborhood of 60 to 75 per cent. of the bacteria. Where these filters treat the effluent of a septic tank in which are removed about two thirds of the bacteria in the raw sewage, the total bacterial purification approximates 90 per cent.

The available data indicate that the removal by either process of pathogenic and non-pathogenic forms is in fairly direct proportion, generally speaking. In studying the effect which these remaining forms of pathogenic bacterial life in sewage effluents may have upon the water supply of neighboring cities, it is important to obtain light upon the longevity of the typhoid bacillus in this connection.

Self-purification of streams, or more strictly speaking, the length of life of the typhoid bacillus in water, is a question most intimately related to subjects having to do with the pathogenicity of sewage effluents. As to methods for destroying these

pathogenic forms, two may be prominently considered, namely: first, their destruction through natural causes in water; and second, their destruction by germicidal chemicals. Although somewhat foreign to the subject of this paper, it is thought that perhaps the information recently obtained at the Columbus Sewage Testing Station upon the question of the methods of testing the longevity of the typhoid bacillus in sewage and water may be of interest in this connection.

LONGEVITY OF THE TYPHOID BACILLUS IN SEWAGE AND WATER.

Without going into a lengthy discussion of the literature bearing upon this question, it may be said that the researches of the Massachusetts State Board of Health [1] at the Lawrence Experiment Station indicated that the typhoid bacillus lived in river water in decreasing numbers for at least about three weeks. Sedgwick and Winslow [2] showed with considerable clearness that certain resistant forms of the typhoid bacillus will live for an almost indefinite period of time in still water, ice, or moist earth. Horrocks [3] concludes that typhoid will live in sterile sewage for sixty days, but that in unsterilized sewage typhoid will die out in fourteen days. Pickard [4], in a study of the longevity of the typhoid bacillus at Exeter, found that about 99 per cent. of these organisms died out in fourteen days in septic sewage. Martin [5] showed that in sterile soil containing sewage matters, typhoid bacilli were able to survive for four hundred and fifty days, but in unsterile soil of a similar character he places the limit of longevity at fifty days. Karlinski [6] states that typhoid bacilli may exist in soil for more than three months. In feces it has been found to survive for at least eight months at Canton, Mass., according to Professor Mason.[7]

Quite recently the results of two series of very similar investigations of a particularly extensive character have been placed on record. The methods of procedure in these two investigations were essentially the same, consisting in the suspension of sacs composed of collodion, parchment, or celloidin, containing known quantities of typhoid bacilli, in flowing streams of Lake Michigan water, and of crude and diluted sewages. The numbers of typhoid in small volumes of the water in the sacs were painstakingly determined at intervals by the most modern methods.

The use of these sacs was considered to be quite an improvement over tests made in bottles, in that the germs were supposed to be confined and at the same time the water within and without the sacs was interchanged by dialysis.

The results of one of these investigations [8] showed that while about 95 per cent. of the typhoid germs died out in running streams of Lake Michigan water in a week or ten days' time, after which there seemed to be practically no further reduction. In general, these data are in harmony with previously obtained information on the subject. The other investigation,[9] conducted under somewhat similar conditions, indicated that the typhoid bacilli were completely eliminated in about ten days, and that in flowing streams of crude and diluted sewage the destruction of these germs took place with even greater rapidity, all organisms of this type being destroyed under these conditions in from three to four days, according to these observations.

These somewhat conflicting data (the conclusions of Frost and of Jordan, Russell and Zeit, respectively) suggest the possibility that the collodion sacs offered less opportunity for the exit of the highly motile typhoid bacilli through the walls of the sacs than did the sacs of parchment. If this was not so, the thought presents itself that possibly after several days of service the initial integrity of the parchment sacs was impaired to an extent sufficient to permit of the escape therefrom of the typhoid bacilli. To place the results of studies of this character upon a perfectly sound basis, positive data and statements are required to show whether the initial bacterial integrity of the sacs containing the typhoid bacilli continued unimpaired throughout the experiment.

Such definite information as referred to is called for, in the opinion of the writer, for the reason that studies in this line made at the Columbus Sewage Testing Station have shown that in some instances parchment sacs which possessed perfect integrity initially, and retained it throughout the experiments, so far as their dialyzing properties were concerned, permitted the escape therefrom of *bacillus coli* when immersed in distilled water, and when submerged in flowing sewage and polluted water permitted the entrance, in a comparatively short time, of large numbers of motile bacteria, including *B. coli*. Typhoid bacilli were not

studied in this connection, but the conclusion may be justly drawn, in view of the highly motile character of the typhoid bacillus, that if other less motile forms could pass through the walls of the unpunctured parchment sacs under such conditions, there is no room for reasonable doubt regarding the ability of typhoid bacilli to act in a similar manner. The results of the Columbus studies referred to are presented in the following tables:

TABLE OF RESULTS ILLUSTRATIVE OF THE PASSAGE OF B. COLI THROUGH THE WALLS OF UNPUNCTURED PARCHMENT SACS FROM THE OUTSIDE.

Sacs Suspended in a Flowing Stream of	B. coli per c.c. in the Water Contained in the Sacs.		
	Number of Hours the Sacs were Exposed in Current.		
	0	48	72
Crude sewage	0	320	2 000
Septic sewage	0	320	2 000
Septic sewage	0	120	1 100
Eff. of a sewage filter ..	0	400	2 000
Polluted water	0	0	40

TABLE OF RESULTS ILLUSTRATIVE OF THE ESCAPE OF B. COLI FROM PARCHMENT SACS WHEN IMMERSED IN VESSELS OF STERILIZED WATER.

Number of Hours the Sacs were Suspended in the Sterilized Water.	B. coli per c.c. in the Water Surrounding the Sacs.		
	Sac: a	b	c
0	Over 1 000	Over 1 000	Over 1 000
24	0	0	0

NOTE: The dialyzing integrity of all the sacs used in the above studies continued unimpaired throughout the experiment.

REDUCTION OF THE PATHOGENICITY OF SEWAGE AND SEWAGE EFFLUENTS BY CHEMICAL COMPOUNDS.

The idea of sterilizing sewage and sewage effluents is not new. About thirty years ago the Rivers Pollution Commission of England was instrumental in setting on foot a movement looking to

the sterilization of sewagic matter. In 1900, in the Interim Report of the Royal Commission on Sewage Disposal of Great Britain, the statement is made that the commission was considering whether means were available whereby the destruction of such pathogenic bacteria as escaped in the effluents of artificial purification processes could be brought about in a practicable manner. The question was more exhaustively treated in their report for 1902, but led to no positive result other than a recommendation on the part of the commission that scientific studies be carried on to ascertain the extent of the danger of bacterial pollution against which their rivers should be protected.

The difficulty in bringing about the absolute sterilization of sewage obviously relates to the cost entailed by the use of an active and reliable germicide. Manganate of soda was used as a deodorant for a time in London, pending the opening of the precipitation works at that place. Permanganate of potash has been made use of for sterilizing purposes by the British army in India. Bleaching powder was used for sterilizing the water supply during the typhoid epidemic at Maidstone in 1897. Electrozone has proven under favorable conditions to be an efficient sterilizing agent, as has the more highly expensive peroxide of chlorine. During 1904, the efficiency of oxychloride as a germicide when applied to sewage effluents was demonstrated by Dr. Rideal,[10] who, as a result of his studies, stated that he found the process practical, effectual, and economical. The efficiency of ozone as a germicide when adequately applied to water is well known. Recently the value of metallic salts, such as copper sulphate and copper chloride, has received particular attention in this connection.

Copper chloride and copper sulphate, used for many years past by canning industries to prevent bacterial fermentation, have been experimented with by many investigators to determine their effect on pathogenic organisms. In 1904, in experiments of this character, presumably suggested by the revival on the part of the United States Department of Agriculture of questions relating to the efficiency of copper sulphate as a germicide, Rideal and Baines [11] showed that, when applied to flasks of boiled distilled water and flasks of filtered tap water, both of which had

been inoculated with *bacillus coli* and *bacillus typhosus*, respectively, copper sulphate in the proportion of 1 to 5 000 destroyed coli in one hour's contact, but not typhoid. Similarly, with copper chloride, 1 in 26 000 destroyed coli in three hours and typhoid in one hour. In concentration of 1 in 100 000, both coli and typhoid successfully resisted both copper sulphate and copper chloride for at least twenty hours, the maximum period over which the experiments were extended.

The results of the researches of Moore and Kellerman [12] in this connection are widely known. Their conclusions regarding the germicidal effect of copper sulphate upon *bacillus typhosus* are that "it should prove particularly useful in very large water supplies accidentally or suddenly contaminated with typhoid bacilli and not provided with any adequate means of purification." They further state that "in general, an epidemic could be controlled and quickly eradicated by a solution much weaker than 1 in 100 000, listed as necessary for complete sterilization, within twelve hours."

Soon after the work at the Columbus Sewage Testing Station was inaugurated, Bulletion No. 64 of the United States Department of Agriculture appeared, giving a *résumé* of the practical results obtained from the treatment of waters with copper sulphate for the elimination of algal growths. Incidental mention was also made of the indications that this chemical might have considerable value in the prevention of typhoid fever, through its application to polluted water supplies at times of typhoid fever epidemics. The subject appeared to be of sufficient importance to merit a study of the effect of copper sulphate when applied to sewage and sewage effluents, and the results of such studies made at the Columbus Testing Station, and the practical conclusions which it has been possible to draw therefrom are next presented.

AN OUTLINE OF THE STUDIES MADE AT THE COLUMBUS SEWAGE TESTING STATION ON THE EFFECT OF COPPER SULPHATE AS A GERMICIDE WHEN APPLIED TO SEWAGE AND SEWAGE EFFLUENTS.

Lack of time has prevented the working out of many highly desirable features in connection with the subject at hand, but

some points of practical significance have been brought out in our work, the substance of which is now presented. The work was aimed particularly at the following questions:

1. Rapidity of the germicidal action of copper sulphate.
   (*a*) The effect of temperature.
   (*b*) The effect of organic matter.
   (*c*) The effect of carbonates dissolved in the sewage.
2. Amounts of copper sulphate required:
   (*a*) For the reduction of total numbers of bacteria.
   (*b*) For the destruction of bacteria in feces.
   (*c*) For the destruction of *bacillus coli*.
   (*d*) For the destruction of *bacillus typhosus*.

The manner of conducting the experiments may be briefly described as follows:

The effect of the copper sulphate treatment was studied in connection with crude sewage, the effluents of certain coarse-grain beds, the effluents of sand filters, fresh feces diluted with sterilized distilled water, and with sterilized distilled water inoculated with pure cultures of *bacillus typhosus*.

All tests were made in volumes of at least 100 cubic centimeters, and the copper sulphate was added in the form of an aqueous solution, freshly prepared for each test. The chemical was ordinary commercial copper sulphate ($CuSO_4 + 5H_2O$), and was found on analysis to be 95 per cent. pure. Except where otherwise stated, the test flasks were kept at a constant temperature of 20° C. The culture media employed in the work were prepared in strict accordance with the methods recommended by the Committee on Standard Methods, 1905.[13] The numbers of bacteria were determined after incubation of the gelatine plate cultures for forty-eight hours at 20° C. In the tests to show the reduction in numbers of *bacillus coli* and *bacillus typhosus*, strict determinative differentiating tests were employed in all cases, that no doubt might remain regarding the identity of these organisms before and after the copper sulphate treatment. These tests were carried out in the manner described by the Committee on Standard Methods, 1905.

The results presented below represent in each instance the averages of from three to five separate series of tests. It may be

of interest to record the fact that no startlingly radical differences were noted in the results of the individual tests.

Acknowledgment here is due and gratefully made to Mr. W. R. Copeland and Mr. C. B. Hoover for the important part which they took in the studies outlined above. A preliminary report of the results of these experiments was presented at the Havana meeting of the American Public Health Association.[14]

THE EFFECT OF COPPER SULPHATE ON THE BACTERIAL CONTENT OF SEWAGE AND SEWAGE EFFLUENTS.

The results presented in Tables Nos. 1, 2, 3, and 4 show that when used in the proportion of 1 to 1 000, the germicidal action of the chemical continues uninterruptedly for twenty-four hours. Apparently the chemical must be added in quantities in excess of 1 part in 10 000 to prevent the bacteria from increasing in numbers after a period of contact of about six hours.

EFFECT OF ORGANIC MATTER AND DISSOLVED CARBONATES ON THE GERMICIDAL POWER OF COPPER SULPHATE IN SEWAGE AND SEWAGE EFFLUENTS.

In the tests designed to show the effect of organic matter and alkalinity on the germicidal power of copper sulphate in sewage and sewage effluents, crude sewage and the respective effluents of a sprinkling filter and a sand filter were used. The flask cultures were prepared in triplicate, namely, undiluted, and diluted one to one and one to two parts of distilled water, respectively.

The results presented in Tables Nos. 5, 6, and 7 indicate that while there appears to be a fairly well-defined tendency for the germicidal power to increase as the amount of organic matter is diminished, within the limits of our tests the differences thus shown were too slight to be of practical significance.

EFFECT OF TEMPERATURE ON THE GERMICIDAL POWER OF COPPER SULPHATE.

The results presented in Table No. 8 bring out forcibly the effect which low temperatures have in slowing down the germi-

cidal action of copper sulphate. In a general way, irrespective of the amount of chemical used, 2½ times as many bacteria were destroyed after one-half hour in the flasks set at 20° C. as in the flasks set at 5° C.; 15 times as many after two hours, and 20 times as many after six hours. At the end of eighteen hours the numbers of bacteria in the flasks containing the lowest amount of chemical had increased to a point where further comparison of this character was made impossible. There were no such increases noted in the flasks kept at the low temperature.

EFFECT OF COPPER SULPHATE ON THE BACTERIAL CONTENT OF FECES.

In this test 5 grams of fresh feces were diluted with 1 500 cubic centimeters of sterilized distilled water. Two sets of flask cultures were prepared, one set being placed at a temperature of 5° C., and the other at 25° C. The control cultures showed the characteristic effect of temperature on the rate of multiplication of bacteria under such conditions, and the effect of temperature on the germicidal power of copper sulphate was again clearly brought out.

The rapidity of action of the chemical was normal. An interesting fact was brought out during this test, when it was shown that the control cultures contained no spore-forming bacteria. This fact effectually disposed of the suspicion that the bacteria which were able to withstand the high concentrations of the chemical, and even increase prodigiously in numbers after a time, might be enabled to do so by their spore-forming proclivities.

EFFECT OF COPPER SULPHATE ON BACILLUS COLI IN CRUDE SEWAGE AND SEWAGE EFFLUENTS.

In Tables Nos. 10, 11, and 12 are presented the results of tests to show the effect of copper sulphate on *bacillus coli* in sewage and in sewage effluents. As previously mentioned, all of the differential tests for *bacillus coli* were determinative.

The results show that when the chemical was applied to crude sewage in the proportion of 1 to 10 000, the coli were exterminated within one hour. In concentrations of 1 to 50 000, 200 *bacillus*

coli persisted for one hour; 10 for six hours; and all of the *bacillus coli* were dead at the end of twenty-four hours. In the culture flasks prepared from the effluent of a sprinkling filter, 10, 20, and 100 *bacillus coli* persisted for one hour in concentrations of one part of copper sulphate in 1 000, 5 000, and 50 000 parts of effluent, respectively. Tests made at the end of six hours showed all of the *bacillus coli* to be dead in all of the flasks. In the flasks prepared from the effluent of a sand filter, the coli were apparently all dead at the end of one hour in the flasks where the chemical was used in the proportion of 1 to 1 000. In those flasks where the concentrations were 1 in 10 000, 50 coli persisted for one hour, and one for six hours. All *bacillus coli* were dead at the end of twenty-four hours.

EFFECT OF COPPER SULPHATE ON BACILLUS TYPHOSUS.

The severest test of all, from the standpoint of the ability of the organism to resist the effect of the chemical, was applied in connection with studies designed to show the effect of copper sulphate on *bacillus typhosus*. Flasks in duplicate of sterilized water were inoculated with a culture of *bacillus typhosus*. One set of flasks was set at a temperature of 7° C., the other at 28° C. The typhoid cultures used were obtained from Parke, Davis & Co., and from the Ohio State University. The former culture was apparently fresh, while the latter was an old stock culture. Both were rejuvenated before use in accordance with the method recommended by the Committee on Standard Methods, 1905, and readily responded to the agglutination test when the experiment was begun.

At a temperature of 7° C., the control culture showed a reduction in the number of typhoid bacilli from 200 000 to 8 000, or about 96 per cent., in forty-eight hours. Small numbers of typhoid persisted in all of the treated flasks for forty-eight hours at this temperature. Concentrations ranging from 1 in 50 000 to 1 in 4 000 000 were used.

At a temperature of 28° C., 75 out of 200 000 typhoid persisted in a concentration of 1 in 50 000 for one hour, but all were apparently dead at the end of four hours. In a concentration of

1 in 100 000, 550 typhoid bacilli were alive at the end of one hour; 10 at the end of four hours; and 1 at the end of seven hours. The weaker concentrations showed a fairly consistent falling off in germicidal power as the amount of the chemical was decreased.

TABLE No. 1.

COPPER SULPHATE *vs.* BACTERIA IN CRUDE SEWAGE.

Initial Composition of Sewage. { Organic Nitrogen, 6.3 parts per million. Alkalinity, 376 „ „ „ Bacteria, 1 200 000 per cubic centimeter.

	BACTERIA PER C.C. TOTAL NUMBERS.			
Hours of Contact.	0	1	6	24
$CuSo_4$ 0	1 200 000	1 200 000	6 000 000	14 000 000
„ 1 in 1 000	1 200 000	3 000	190	35
„ 1 „ 10 000	1 200 000	9 500	250	200
„ 1 „ 50 000	1 200 000	14 000	700	3 400 000

TABLE No. 2.

COPPER SULPHATE *vs.* BACTERIA IN THE EFFLUENT OF A SPRINKLING FILTER.

Initial Composition of Effluent. { Organic Nitrogen, 4.0 parts per million. Alkalinity, 290 „ „ „ Bacteria, 1 000 000 per cubic centimeter.

Hours of Contact.		1	3	6	24
Average Number of Bacteria per Cubic Centimeter.	$CuSo_4$ 0	1 000 000	2 200 000	3 300 000	3 300 000
	„ 1 in 1 000	1 000	240	75	49
	„ 1 „ 5 000	5 000	600	170	80
	„ 1 „ 10 000	6 000	500	190	130
	„ 1 „ 25 000	3 400	700	310	360 000
	„ 1 „ 50 000	11 000	1 900	1 200	1 100 000
	„ 1 „ 100 000	21 000	4 500	3 500	3 500 000

TABLE No. 3.

COPPER SULPHATE *vs.* BACTERIA IN THE EFFLUENT OF A CONTACT BED.

Initial Composition of Effluent. { Organic Nitrogen, 2.7 parts per million. Alkalinity, 320 „ „ „ Bacteria, 400,000 per cubic centimeter.

Hours of Contact.		1	3	6	24
Average Number of Bacteria per Cubic Centimeter.	$CuSO_4$ 0	600 000	850 000	1 200 000	1 600 000
	„ 1 in 1 000	430	60	40	30
	„ 1 „ 5 000	1 100	130	65	45
	„ 1 „ 10 000	2 100	230	100	250
	„ 1 „ 25 000	1 200	230	430	37 000
	„ 1 „ 50 000	3 500	600	1 100	65 000
	„ 1 „ 100 000	7 500	1 200	1 800	800 000

TABLE No. 4.

COPPER SULPHATE *vs.* BACTERIA IN THE EFFLUENT OF AN INTERMITTENT SAND FILTER.

Initial Composition of Effluent. { Organic Nitrogen, 0.87 parts per million. Alkalinity, 270 „ „ „ Bacteria, 280 000 per cubic centimeter.

Hours of Contact.		1	3	6	24
Average Number of Bacteria per Cubic Centimeter.	$CuSO_4$ 0	310 000	410 000	440 000	700 000
	„ 1 in 1 000	2 100	280	70	22
	„ 1 „ 5 000	6 000	1 400	350	40 000
	„ 1 „ 10 000	5 500	1 800	430	90 000
	„ 1 „ 25 000	6 500	1 300	800	100 000
	„ 1 „ 50 000	13 000	2 600	3 000	470 000
	„ 1 „ 100 000	20 000	5 000	5 500	450 000

TABLE No. 5.

COPPER SULPHATE *vs.* BACTERIA IN UNDILUTED AND DILUTED CRUDE SEWAGE.

(Tests for Numbers of Bacteria made at Start, and after 1 Hour's Contact.)

Parts of Dilution Water (H_2O).		0	1	2
Parts per Million.	Organic Nitrogen	8.9	4.4	3.0
	Alkalinity	400	200	133
Average Number of Bacteria per Cubic Centimeter.	Before adding $CuSO_4$	3 300 000	1 900 000	1 200 000
	$CuSO_4$ 1 in 1 000	2 300	1 600	950
	" 1 " 5 000	5 000	4 000	1 000
	" 1 " 10 000	12 000	9 000	2 200
	" 1 " 25 000	23 000	12 000	1 100
	" 1 " 50 000	68 000	30 000	8 000
	" 1 " 100 000	128 000	46 000	17 000
Average number in all treated flasks .		40 000	17 000	5 000
Percentage reduction		98.8	99.1	99.6

TABLE No. 6.

COPPER SULPHATE *vs.* BACTERIA IN THE UNDILUTED AND DILUTED EFFLUENT OF A SPRINKLING FILTER.

(Tests for Numbers of Bacteria made at Start, and after 1 Hour's Contact.)

Parts of Dilution Water (H_2O).		0	1	2
Parts per Million.	Organic Nitrogen	6.7	3.3	2.2
	Alkalinity	328	164	101
Average Number of Bacteria per Cubic Centimeter.	Before adding $CuSO_4$	550 000	300 000	170 000
	$CuSO_4$ 1 in 1 000	850	500	400
	" 1 " 5 000	3 700	1 800	500
	" 1 " 10 000	6 000	3 800	1 900
	" 1 " 25 000	5 500	3 100	1 200
	" 1 " 50 000	8 500	3 900	2 100
	" 1 " 100 000	15 000	3 000	1 600
Average number in all treated flasks .		6 600	2 700	1 300
Percentage reduction		98.8	99.1	99.2

TABLE No. 7.

COPPER SULPHATE *vs.* BACTERIA IN THE UNDILUTED AND DILUTED EFFLUENT OF AN INTERMITTENT SAND FILTER.

(Tests for Numbers of Bacteria made at Start, and after 1 Hour's Contact.)

Parts of Dilution Water (H_2O)		0	1	2
Parts per Million.	Organic Nitrogen	1.62	0.81	0.54
	Alkalinity	360	180	120
Average Number of Bacteria per Cubic Centimeter.	Before adding $CuSO_4$	200 000	130 000	100 000
	$CuSO_4$ 1 in 1 000	5 500	3 300	2 700
	" 1 " 5 000	18 000	18 000	2 100
	" 1 " 10 000	12 000	5 000	1 200
	" 1 " 25 000	18 000	6 500	2 000
	" 1 " 50 000	48 000	15 000	6 000
	" 1 " 100 000	60 000	19 000	9 000
Average number in all treated flasks .		26 900	11 100	3 800
Percentage reduction		87	91	96

TABLE No. 8.

EFFECT OF TEMPERATURE ON THE GERMICIDAL POWER OF COPPER SULPHATE IN A CONTACT BED EFFLUENT.

Concentration of Copper Sulphate Employed.	Temperature at which Flasks were Kept during Test.	Bacteria per Cubic Centimeter. Period of Contact in Hours. 0	0.5	2	6	18
1 in 25 000	5° C.	490 000	37 000	24 000	5 500	1 300
	20	600 000	15 000	1 300	250	350
1 in 50 000	5	500 000	48 000	34 000	3 900	1 800
	20	600 000	18 000	2 900	650	3 900
1 in 100 000	5	460 000	100 000	50 000	24 000	2 600
	20	600 000	44 000	3 300	700	81 000
Percentage Reduction in Numbers.						
1 in 25 000	5	.....	92.5	95.1	98.9	99.7
	20	.....	97.5	99.7	99.9	99.9
1 in 50 000	5	.....	90.4	93.2	99.2	99.6
	20	.....	97.0	99.5	99.9	99.3*
1 in 100 000	5	.....	78.3	89.1	94.8	99.4
	20	.....	92.7	99.5	99.9	86.5*

* NOTE. — These figures are distorted by increases in the number of bacteria after the chemical lost its germicidal power.

TABLE No. 9.

Copper Sulphate *vs.* Fecal Bacteria.

(Five grams fresh feces in 1 500 c.c. sterilized distilled water.)

Bacteria per c.c.	Flasks Standing at 5° C.					Flasks Standing at 25° C.				
Hours Contact	0	1	3	6	28	0	1	3	6	28
$CuSO_4$ 0	800	600	1 200	1 200	600	800	1 200	1 200	2 800	2 000 000
" 1 in 50 000	800	600	360	270	21	800	25	2	0	5
" 1 " 100 000	800	550	260	120	15	800	15	1	0	7 700
" 1 " 250 000	800	500	500	400	35	800	50	15	2	13 000
" 1 " 500 000	800	500	750	490	100	800	100	23	10	12 000
" 1 " 1 000 000	800	1 200	500	330	70	800	100	38	25	17 000
" 1 " 2 000 000	800	300	900	700	450	800	600	100	65	10 000
" 1 " 4 000 000	800	800	700	700	550	800	600	450	500	110 000

TABLE No. 10.

Copper Sulphate *vs.* Bacillus Coli in Crude Sewage.

Initial Composition of Sewage.
- Organic Nitrogen, 6.3 parts per million.
- Alkalinity, 376 " " "
- Bacteria, 1 200 000 per cubic centimeter.
- B. coli communis, 10 000 per cubic centimeter.

Bacteria per c.c.	Total Numbers.				B. Coli.			
Hours Contact ..	0	1	6	24	0	1	6	24
$CuSO_4$ 0	1.2*	1 200 000	6 000 000	14 000 000	10 000	20 000	40 000	40 000
" 1 in 1 000	1.2*	3 000	190	35	10 000	0	0	0
" 1 " 10 000	1.2*	9 500	250	200	10 000	0	0	0
" 1 " 50 000	1.2*	14 000	700	3 400 000	10 000	200	10	0

* Note. — Million.

TABLE No. 11.

Copper Sulphate *vs.* Bacillus Coli in the Effluent of a Sprinkling Filter.

Initial Composition of Effluent.
- Organic Nitrogen, 2.0 parts per million.
- Alkalinity, 248 " " "
- Bacteria, 300 000 per cubic centimeter.
- B. coli communis, 2 000 per cubic centimeter.

Bacteria per c.c.	Total Number.				B. Coli.			
Hours of Contact ..	0	1	6	24	0	1	6	24
$CuSO_4$ 0	300 000	380 000	750 000	300 000	2 000	2 000	5 000	10 000
" 1 in 1 000	300 000	150	65	80	2 000	10	0	0
" 1 " 10 000	300 000	2 500	125	300	2 000	20	0	0
" 1 " 50 000	300 000	95 000	500	200 000	2 000	100	0	0

TABLE No. 12.

Copper Sulphate *vs.* Bacillus Coli in the Effluent of an Intermittent Sand Filter.

Initial Composition of Effluent. { Organic Nitrogen, 0.46 parts per million. Alkalinity 240 „ „ „ Bacteria, 29 000 per cubic centimeter. B. coli communis, 1 000 per cubic centimeter.

Bacteria per c.c.	Total Numbers.				B. Coli.			
Hours of Contact ..	0	1	6	24	0	1	6	24
$CuSO_4$ 0	29 000	40 000	45 000	270 000	1 000	1 000	3 000	5 000
„ 1 in 1 000	29 000	50	3	6	1 000	0	0	0
„ 1 „ 10 000	29 000	100	10	50	1 000	50	1	0
„ 1 „ 100 000	29 000	200	10	3 500	....	....	....	....

TABLE No. 13.

Copper Sulphate *vs.* Bacillus Typhosus.

(Flasks of sterilised water, H_2O, inoculated with rejuvenated culture of *bacillus typhosus*. Number of typhoid at start, 200 000 per cubic centimeter.)

Hours of Contact.	Flasks Standing at 7° C.				Flasks Standing at 28° C.			
	1	4	7	48	1	4	7	48
$CuSO_4$ 0	150 000	50 000	50 000	8 000	290 000	178 000	140 000	220 000
„ 1– 50 000	21 000	3 100	700	2	75	0	0	0
„ 1–100 000	25 000	2 400	700	4	550	10	1	0
„ 1–500 000	21 000	1 600	900	3	800	15	3	0
„ 1–1 000 000	19 000	1 800	500	65	1 500	50	7	0
„ 1–2 000 000	32 000	10 000	12 600	120	11 000	150	10	1
„ 1–4 000 000	92 000	63 000	31 000	5 500	6 000	60	15	4

BRIEF DISCUSSION OF THE TABLES.

Except for the purpose of making the data as complete as possible, the effect of copper sulphate on the total numbers of bacteria in sewage and sewage effluents has but little direct bearing on the matter at hand. As shown by the results presented above, there are some forms of bacterial life which are able to resist the action of copper sulphate for days, and for some or all of these forms, in cases where less than 1 part of the chemical in 10 000 parts of sewage or sewage effluent is used, copper sulphate loses

its germicidal power after about six hours, and from that time on these forms continue to rapidly increase in numbers. So far as is known, and judging from the results of our tests, these resisting forms are non-pathogenic.

The deleterious effect of organic matter and dissolved carbonates on the germicidal power of copper sulphate has not been clearly brought out in our tests. They are doubtless somewhat of a factor, but within practical limits, judging from the results presented above, they cannot be considered as materially disturbing elements.

The effect of temperature is the most important physical feature among factors which have to do with the germicidal power of this chemical. The significance of this fact is immediately apparent when it is recalled that it is frequently during the cool weather that the elimination of the typhoid bacillus is the most urgently desired. During extreme cold weather, when the water approaches the state of maximum density, the action of copper sulphate as a germicide is very slow, relatively speaking, and the results presented in Table No. 13 show that a comparatively large number of typhoid bacilli resisted the action of this chemical, when used in the proportion of 1 in 50 000 for a period of seven hours. Attention is here called to the fact indicated by the results in Table No. 13, that at a low temperature concentrations of 1 in 1 000 000 will effect on typhoid practically the same result as would a concentration of 1 in 50 000; but that lower concentrations than 1 in 1 000 000 give markedly inferior results. At the warmer temperatures the same thing is true in a measure, although there is a sharper gradation in the germicidal power of the chemical as the concentrations are increased. Where the storage facilities were adequate to permit of a period of contact of several hours, as weak a concentration as 1 in 1 000 000 would be practically as effective as one twenty times as great so far as killing the great majority of the typhoid germs is concerned.

As to the effect of copper sulphate on *bacillus coli* in sewage and sewage effluents, it seems reasonable to assume that, within limits, the points established in connection with this organism may be applied with a considerable degree of directness to the typhoid bacillus. It was deemed to be impracticable to attempt

a study of the effect of the chemical upon the typhoid bacillus in unsterilized sewage and sewage effluents, and *bacillus coli* was studied in its stead. All of these tests were made at a comparatively high temperature, 20° C., and the results showed that, generally speaking, a considerable number of these organisms could and did resist the germicidal effect of the chemical for something like six hours or more, in both sewage and sewage effluents, when as high a concentration of the copper sulphate as 1 in 50 000 was employed.

COST OF COPPER SULPHATE.

In Table No. 14 there are listed the various concentrations employed in the tests above described, giving also corresponding figures to show the amounts of the chemical in grains per gallon, pounds per million gallons, and cost for chemical per million gallons. In these figures only the bare cost of the chemical is given, no allowance being made for the cost of devices for its application, or for supervision and attendance charges.

TABLE No. 14.

COST OF COPPER SULPHATE PER MILLION GALLONS.

Concentration.	Grains per Gallon.	Pounds per Million Gallons.	Cost for Chemical per Million Gallons @ $0.06 per Pound.
1 in 1 000	58.500	8 357.1	$501.43
1 „ 5 000	11.700	1 671.4	100.29
1 „ 10 000	5.850	835.7	50.14
1 „ 25 000	2.340	334.3	20.06
1 „ 50 000	1.170	167.1	10.03
1 „ 100 000	0.585	83.6	5.01
1 „ 250 000	0.234	33.4	2.01
1 „ 500 000	0.117	16.7	1.00
1 „ 750 000	0.078	11.1	0.67
1 „ 1 000 000	0.058	8.4	0.50
1 „ 2 000 000	0.029	4.2	0.25
1 „ 3 000 000	0.019	2.8	0.17
1 „ 4 000 000	0.014	2.1	0.13
1 „ 5 000 000	0.012	1.7	0.10

SUMMARY AND CONCLUSIONS.

The evidence seems to be reasonably sound that certain types of the typhoid bacillus, possessing special powers of resistance,

may successfully evade not only natural destruction when found outside the human body, but also almost all reasonable attempts toward their extermination by the use of copper sulphate when applied within practicable limits of economy on a large scale. These especially hardy types constitute perhaps but a small fraction of all typhoid bacilli, but even so, they are a specific menace to the public health.

There is ample evidence on record to prove beyond peradventure that, through natural causes, the vast majority of typhoid germs die out fairly quickly in sewage and running water into which they find their way. The data are quite as conclusive that artificial purification of sewage by fine-grained filters will result in a substantial elimination of such organisms. That complete sterilization of sewage effluents and polluted water may be effected by chemical means is also an indisputable fact, but the difficulty and cost entailed by their entirely successful use are decided drawbacks to their practical application.

With increasing knowledge of the difficulties and expense of hygienically treating at sewage works the entire water-carried wastes of a city, the more practical and important becomes the plan of thoroughly disinfecting all dejecta before they leave the sick room. Here it can be done effectively at small cost.

While the effluents of all artificial processes may perhaps be properly regarded as "potentially dangerous," the effluent of a process where sand filtration at low rates is employed for the purification of sewage is undoubtedly the most desirable hygienically of all the known processes which have been practiced to date. The treatment of sewage on sand filters, however, is very expensive for some localities, particularly where the material for the sand beds must be transported from a distance. In some places its cost would be prohibitive. Sewage treatment in coarse-grain filters is apparently much less expensive under ordinary conditions. The effluent of such works is decidedly inferior hygienically to that obtainable from sand filters. It does not seem improbable, therefore, that in some localities a place of usefulness will be found for copper sulphate, in reducing the pathogenicity of coarse-grain filter effluents to a point where they will be comparable with those from sand filters.

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EXPERIMENTS UPON THE REMOVAL OF MICROSCOPIC ORGANISMS FROM PONDS AND RESERVOIRS BY THE USE OF COPPER SULPHATE.

BY X. H. GOODNOUGH.*

The possibility of the removal of microscopic organisms from the waters of ponds and reservoirs by the use of copper sulphate was brought to the attention of the State Board of Health of Massachusetts by Dr. George T. Moore some three years ago, and experiments upon this method of improving the water of reservoirs affected by such growths were begun under my direction in the year 1903. The work has been carried on by Mr. Henry E. Mead, an assistant engineer of the State Board of Health, and during the past two years five ponds and reservoirs have been treated with copper sulphate, some of them several times, and the results observed. In addition, the results of the application of copper sulphate to two other ponds and reservoirs by persons not connected with the State Board of Health have been noted.

The application of the copper sulphate was made in the earlier cases under the advice of Dr. Moore and under the immediate

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direction of his assistants, Messrs. Kellerman and Robinson, and in the later cases by Mr. Mead, who has followed the methods in which he was instructed.

It is impossible to do more in the time reasonably allowable for a discussion of the papers presented than to give an outline of these experiments and refer briefly to the results.

The sources which have been used for experiment are the Belchertown reservoir in the town of Belchertown, Mass., used formerly as a source of public water supply by the city of Springfield, and the Arlington, Lexington, and Quincy storage reservoirs, and Jamaica Pond, formerly used as sources of water supply by portions of the Metropolitan district near Boston. The biological and chemical characteristics of most of these waters were very well known, as a result of frequent examinations of their waters covering periods, in most cases, of many years. Fewer examinations had been made of the water of Belchertown reservoir before the experiments were begun than of any of the others, but enough was known to show that this reservoir was affected annually by the presence in the summer season of great numbers of the organism *Anabæna*.

BELCHERTOWN RESERVOIR.

Belchertown reservoir was originally constructed for mill purposes many years before it was used as a source of water supply. Its area is about 35 acres, its general depth from 4 to 5 feet when full to the level of the overflow, the maximum depth being 7 feet, and it holds when full about 56 000 000 gallons. The bottom is of mud, and the drainage area of about 3.2 square miles contains large areas of swamp. Over much of the area of the reservoir the water is ordinarily covered with growths of *chara*, pond lilies, and water weeds of various sorts. The reservoir contains the fish common to this region. The water is highly colored and contains practically at all times a large quantity of organic matter.

This reservoir was first treated with copper sulphate on July 21, 1904, in a quantity amounting to 1 part of copper sulphate to 8 000 000 parts of water, *Anabæna* having appeared earlier in the month and increased until the filaments numbered 1 200 per cubic centimeter. There were also other organisms

present in the water, about ten different kinds being noted, but the numbers of each were small. The copper was applied at the Belchertown reservoir and also in all of the other cases by placing it in gunny sacks and trailing it through the water at the stern of a boat until the copper became thoroughly dissolved, effort being made to reach all parts of the reservoir.

After the application of the copper to Belchertown reservoir on July 21, 1904, the numbers of *Anabæna* decreased rapidly, and the organism had practically disappeared within six days, though occasionally one or two were found in subsequent samples up to August 18. The numbers of other organisms present in this water also rapidly decreased after the copper was applied, until on the twenty-seventh day of July, within six days after the treatment, they numbered about 370 per cubic centimeter; but from this point they increased with great rapidity to nearly 4 000 per cubic centimeter toward the end of August, and subsequently to nearly 5 000 per cubic centimeter in September. The numbers then gradually fell off with the approach of winter.

The organisms which grew most abundantly after the disappearance of the *Anabæna* were *Asterionella* and *Tabellaria*, and but very few other organisms of any kind were present. At the time of this first treatment three fish — suckers — were found dead in the reservoir. Some doubt was expressed as to whether these fish were killed by the copper.

In 1905, *Anabæna* appeared in Belchertown reservoir much earlier than in the previous year, and by the middle of May the numbers had become excessive. The treatment of the reservoir was delayed until June 13, when copper was applied in a quantity amounting to 1 part in 8 000 000 parts water, the same as in the previous year. After this treatment the numbers of *Anabæna* decreased somewhat, but early in July they began to multiply again and the reservoir was again treated, on July 18, with the same quantity of copper sulphate, 1 part in 8 000 000 parts of water. After this treatment the numbers of *Anabæna* gradually diminished, and none have been found since August 4.

After the disappearance of the *Anabæna*, *Scenedesmus* appeared in large numbers, but at the time of the most recent available examination — August 29 — while the number of genera repre-

sented was much larger than usual, the number of organisms was much smaller than in the previous year, amounting to less than 1 000 per cubic centimeter. No dead fish were found after either of the treatments in 1905, nor did the fish appear to be visibly affected.

The quantity of copper present in the water of the reservoir was found to vary greatly at different times, and some of the samples contained a much greater quantity of copper than the quantity applied, indicating an uneven distribution of the copper in the water at different times. The reservoir is very shallow, as already stated, and the water becomes greatly agitated at times of high winds.

ARLINGTON RESERVOIR.

Arlington reservoir has an area of 29.2 acres at the level of the overflow and holds about 66 000 000 gallons. It is shallow, the maximum depth being about 9 feet, and the general depth not over 7 feet. The watershed at present has an area of about 1.1 square miles. The water is highly colored and contains usually a very large quantity of organic matter. The reservoir has been subject to growths of *Anabæna*, which have sometimes appeared in enormous numbers, but it is not affected by *Anabæna* in every year. It has, however, contained other organic growths which have made the water very objectionable for water supply purposes.

Copper sulphate was applied to the reservoir four times in the years 1903 and 1904. The first application of copper sulphate to this reservoir was made August 5, 1903, and this was the first of the experiments made by the State Board of Health upon the use of copper in clearing reservoirs from organic growths. At the end of June, 1903, the total number of organisms in the reservoir numbered nearly 13 000 per cubic centimeter, consisting chiefly of *Scenedesmus*, *Synedra*, and *Asterionella*. The numbers decreased during July to a miniumm of about 4 000 by the first of August, and then began to increase again, and on August 5 numbered about 5 000 per cubic centimeter, consisting almost wholly of *Scenedesmus*. The quantity of copper sulphate applied was 1 part in 1 500 000 parts of water. After the copper was applied

the number of organisms increased for a day or two and then diminished. They then rapidly increased to a maximum of somewhat more than 8 000 per cubic centimeter, chiefly *Scenedesmus*. Toward the latter part of August they again increased to a maximum of nearly 12 000, *Scenedesmus* continuing to be the principal organism present.

Organisms reappeared in May, 1904, in numbers running up to 18 000 per cubic centimeter, consisting chiefly of *Synedra* and *Scenedesmus*, the organism which was most prominent in the previous year, but after the culmination of this growth in the latter part of May, the number of organisms decreased rapidly until about the middle of June, when the number present had fallen to about 1 000 per cubic centimeter. At this point a growth of *Staurastrum* appeared, and the number of organisms again increased to nearly 9 000 per cubic centimeter by the latter part of June, diminishing by the middle of July to about 1 500, and then rapidly increasing again toward the end of the month to about 6 000, the organisms present being almost a pure culture of *Staurastrum*.

On July 28, copper was again applied in a quantity amounting to 1 part in 3 700 000 parts of water. The growth of organisms decreased for a day or two, but subsequently increased until August 8, when the number had risen to 9 000 per cubic centimeter, still almost wholly *Staurastrum*.

On August 10, copper was again applied in a quantity amounting to 1 part in 700 000 parts of water. The organisms then decreased rapidly for a week, and the *Staurastrum* very soon disappeared almost entirely, but was rapidly replaced by a growth of *Protococcus* and *Scenedesmus* and other organisms until a total of 9 500 was reached near the end of August, when copper sulphate was applied a fourth time on August 30, in a quantity amounting to 1 part in 700 000 parts of water. The organisms then diminished rapidly from 9 500 to about 3 000 in the early part of September. The growth then increased rapidly to more than 11 000 by the middle of October, and remained high until the early part of November, when it gradually diminished as cold weather approached. No fish were killed by the first two treatments of 1 part of copper in 1 500 000 parts of water on

August 5, 1903, or 1 part in 3 700 000 parts of water on July 28, 1904, but the application of copper in a quantity equivalent to 1 part in 700 000 parts of water on August 10, 1904, caused the death of about fifty white perch about six inches in length, but no other dead fish were found, and even while these fish were floating in the water, boys were catching similar fish on the shores of the reservoir. No fish were apparently affected by the application of copper amounting to 1 part in 700 000 parts of water on August 30, notwithstanding the very large quantity of copper which still remained in the reservoir from previous treatments.

Determinations of the quantity of copper present show that it remained in the water of the reservoir in large quantity, though it gradually diminished. The quantity of copper sulphate applied in the three treatments in 1904 amounted to about 1 part in 300 000. On January 9, 1905, the quantity present in the water was 1 part in 7 100 000 parts of water. On June 23, 1905, the quantity of copper found in the water was 1 part in 21 000 000. Microscopical examinations in 1905 show that enormous organic growths still continue in this reservoir. *Synedra* appeared in great numbers early in May, rising to 23 000 per cubic centimeter toward the end of the month, nearly a pure culture of this organism. *Staurastrum* and *Scenedesmus* appeared in July, and *Anabæna* appeared for the first time in this reservoir for several years in August, rising to 176 per cubic centimeter on September 1. The general condition of the reservoir water has been very objectionable both during and since the experiments.

LEXINGTON RESERVOIR.

Lexington reservoir has an area of about five acres and a storage capacity of about eight million gallons. Its depth is about eight feet, and its bottom contains but little mud and organic matter. Soon after its construction in 1893 its water was affected by a considerable number of organisms, chiefly of the smaller kinds, but frequently by the *Infusoria* which have made the water at times objectionable on account of taste and odor. Two experiments have been made in the application of copper sulphate in this reservoir, the first being on February 28, 1905, when the quantity applied was 1 part in 1 000 000 parts of water.

The copper was applied in the usual burlap sacks through a single hole in the ice, the object of applying the copper in this way being to observe its diffusion in the water. Samples were taken before and after treatment at four different points in the reservoir, and at different depths at each point. The results of this test show that the copper settled to the bottom of the reservoir beneath the hole through which it was applied and remained there, spreading but little until the breaking up of the ice on April 4. After the breaking up of the ice, the copper quickly diffused throughout the water of the reservoir, and during April was equally distributed in all portions of it from which samples were taken. In June large quantities of *Uroglena* appeared in the reservoir at a time when the quantity of copper still present in the water amounted to 1 part in 25 000 000 parts of water. Copper was then applied at the rate of 1 part in 20 000 000 parts of water, and on the next day, July 1, the average quantity of copper present in the water was 1 part in 12 000 000 parts of water. The *Uroglena* disappeared in about a week and did not again appear. On July 25 the quantity of copper remaining in the water had diminished to 1 part in 32 000 000.

QUINCY RESERVOIR.

This reservoir has an area of 45 acres and holds when full about 170 000 000 gallons of water. The maximum depth is about 27 feet, and the bottom contains considerable mud and organic matter. The reservoir is made up of two widely separated arms which join at the dam. A large brook flows into the upper end of one of the arms and this stream is the main feeder of the reservoir; the other arm occupies a narrow crooked valley with a very small watershed, and receives no considerable amount of water. The reservoir was built in 1887 as a source of water supply, but its use has been discontinued. The water is considerably colored and contains in the summer season large quantities of organic matter, and frequently numbers of organisms, *Diatomaceæ* being the most abundant, though blue-greens sometimes have been present in large numbers; green algæ and occasionally *Infusoria* have been fairly numerous.

Only one experiment has been made at this reservoir, and the

object in this case was to study the diffusion of copper sulphate. On March 7, 1905, when the reservoir was covered with a foot or more of ice, copper was applied in a quantity amounting to 1 part in 1 000 000 parts of water. All of the copper was applied at the upper end of the arm which receives the main feeder of the reservoir, and all of it was dissolved through a single hole in the ice. Previous to the treatment, samples were taken at nine sampling stations, three in each arm, and three running across the reservoir parallel to the dam and 250 feet from it. Samples were taken frequently until April 7, at which time the ice had disappeared from the reservoir. It was found that the copper settled to the bottom as soon as applied, and while the ice remained moved very slowly toward the dam. No copper appeared in the other arm of the reservoir until after the breaking up of the ice.

The samples collected immediately after the ice disappeared show that the copper had become evenly diffused throughout both arms and all parts of the reservoir. Subsequently, after the stratification of the water in May, the copper appeared to concentrate in the lower layers, though considerable quantities of it still remained in the upper layers of the reservoir.

The watershed of this reservoir is about one thousand acres, and much of the copper was carried out of the reservoir at the time the ice broke up by the freshet flow from the watershed.

JAMAICA POND.

Jamaica Pond is a natural pond, and was the original source of water supply of a portion of the city of Boston. Its use was continued up to 1892. Its area is about seventy acres and it holds about six hundred million gallons of water. It is very deep, with steep shores for the most part, though there is one shallow cove. The maximum depth of the pond is about fifty feet. The watershed is small in proportion to the capacity of the pond, and the water changes very slowly. Under ordinary conditions the water is nearly clear and colorless.

This pond has been affected for many years by enormous growths of the organism *Oscillaria*, which, however, have not appeared in every year, but usually in every other year. The organism appeared in great numbers in the year 1903, and copper

sulphate was applied on September 23 of that year. The quantity applied in this case was 1 part in 1 500 000 parts of water, and in this case a small amount of lime was added three days after the treatment. The *Oscillaria* gradually disappeared from the water and did not appear in 1904.

In the year 1905 the organism again appeared in great numbers, and copper sulphate was applied on August 19 in a quantity amounting to 1 part in 2 000 000 parts of water. The application of the copper took several hours, and it was noticed that fish began to be affected about three hours after the treatment began, and within the week following it is estimated that from 4 000 to 6 000 fish died as a result of the treatment. The fish represented nearly all of the kinds present in the pond, including, it is said, some of the eels. Many of the fish were taken for examination, and all the specimens, with one exception, were found to be females.

The examinations show that the numbers of *Oscillaria* are diminishing and the pond is clearing somewhat, but the results of this test are not yet available.

Samples were collected to determine the quantity of copper present in the pond both before and after treatment. Before treatment, copper was found in quantities ranging from 1 part in about 50 000 000 at the surface to 1 part in 127 000 000 in the bottom water. The copper was applied, as is already stated, on August 19. On August 21 samples were taken at two different places in the pond and at various depths, the results showing that in two samples collected at the surface the quantity was one part in 1.1 millions and one part in 1.4 millions. At a depth of 15 feet the quantities were one part in 4.1 millions and one part in 3 millions, respectively, at the two stations. At a depth of 30 feet the quantity of copper at both stations was 1 part in 32 000 000 parts of water, and at a depth of 45 feet the quantity of copper at one station was 1 part in 47 000 000. The sample from the other station was lost in transit.

Thus it appears that two days after the treatment the copper was concentrated mainly in the upper layers of the pond. The water of this pond becomes markedly stratified in the summer

season, the temperature at the bottom remaining in the neighborhood of 50° F., while the temperature of the surface water rises to that found in other ponds in this region.

Two other tests of the application of copper by persons not connected with the State Board of Health have been made, the results of which have been noted. In Crystal Lake in Newton, a small pond situated in a densely populated residential district, but not used as a source of water supply, *Anabæna* appeared in great numbers early in August, and on August 18 copper sulphate was applied to the water in a quantity amounting to 1 part in 4 000 000 parts of water.

In this instance also a number of fish died, and analyses of samples of water collected on September 1, two weeks after the treatment, showed that the copper remained very largely in the upper layers of the pond, while very little was present in the water nearer the bottom. The *Anabæna* diminished slowly at first and then quite rapidly, until on September 26 the numbers had become insignificant. Other organisms, however, grew rapidly as the *Anabæna* diminished, *Scenedesmus* appearing in very large numbers in the latter part of September. In this pond, as in Jamaica Pond, a great variation in the temperature was noted between the surface and bottom waters, though the depth of the pond is much less than that of Jamaica Pond.

Massapoag Lake in Sharon has an area of about three hundred and fifty acres and is used as a source of ice supply, but not for water supply. The ice company, in order to rid the pond of an excessive growth of *Anabæna*, which is said to have injured the quality of the ice, applied copper sulphate to the water of the lake in October, 1904, in a quantity amounting to 1 part in 5 000 000 parts of water. Subsequent to this treatment the fish died in great numbers, and it is estimated that 250 000 fish of all kinds and sizes were found dead upon the shores of this lake within a short time after the application of the copper sulphate.

SUMMARY.

Summarizing a few of the more notable results of these experiments, it is found that in Belchertown reservoir the copper sul-

phate quickly destroyed the *Anabæna* the first time it was applied at the rate of 1 part in 8 000 000 parts of water. *Anabæna* appeared in the following year much earlier than usual and were not destroyed by an application of the same quanity of copper as in the previous year, but were destroyed by a second application of this quantity. The organisms decreased in numbers much less rapidly than at the time copper was applied in the previous year. After the *Anabæna* had disappeared when copper sulphate was first applied (in 1904), other organisms quickly grew in great numbers. Whether this will be true in the present year remains to be seen.

At Arlington the treatment of the water with copper sulphate even in large quantities had very little effect upon the number of organisms contained in the water, and the condition of this reservoir as regards the presence of organisms was not in any way improved by the application of the copper.

At Jamaica Pond the application of copper sulphate in 1903 destroyed the *Oscillaria* and they did not appear in 1904, though as stated, this organism rarely appears in large numbers in two succeeding years. The *Oscillaria* appeared again in great numbers, however, in 1905, and the numbers have thus far diminished slowly.

Very great differences were found in the effect of the copper upon the fish in the different reservoirs, and great differences in the action of the copper upon the fish in the same reservoir at different times. Practically no fish were killed in the treatment of any of the storage reservoirs — Belchertown, Lexington, Quincy, or Arlington — except that in the latter a small number were killed upon the application of quantities of copper in excess of the amounts usually deemed necessary for the destruction of *Anabæna* and similar organisms. On the other hand, in all of the natural ponds treated, Jamaica Pond, Massapoag Lake, and Crystal Lake, fish were killed, in some cases in enormous numbers. The application of 1 part of copper in 2 000 000 parts of water in Jamaica Pond in August of the present year resulted in the death of many fish, though no fish at all were killed by the application of copper sulphate in September, 1903. The application of copper sulphate to Crystal Lake in an amount equal to one

half the quantity applied at Jamaica Pond about the same date caused the death of numbers of fish, while the application of only 1 part of copper in 5 000 000 parts of water to Massapoag Lake resulted in the death of many thousand. Many of the fish killed in Massapoag Lake and Jamaica Pond were of large size, black bass from four to five pounds in weight being among the victims.

The great differences in the diffusion of copper in water under different conditions are also remarkable. Deposited in a pond under the ice, it sank to the bottom and diffused but slowly until after the breaking up of the ice, but when the ice broke up and the water was completely turned over by the winds in the early spring, the diffusion was complete.

At Belchertown reservoir the copper was found to be highly concentrated in some of the samples. Recent observations upon the application of copper to Jamaica Pond and Crystal Lake show that its diffusion in the summer also may be very slow under some conditions, and that the copper may become highly concentrated in the upper layers of the water.

The results of these experiments show in general that copper sulphate when applied to the water of a pond or reservoir does not in many cases diffuse evenly, and that there is danger that when this substance is applied to waters of ponds or reservoirs used as sources of water supply much stronger solutions of this substance, which is regarded as poisonous even in very small quantities, may be delivered to consumers than is indicated by the ratio of the quantity applied to the total contents of the pond.

DISCUSSION.

Mr. Karl F. Kellerman.* I have very little to say, Mr. President, and I do not want to interfere with what other men who are to participate in this discussion are more able to bring before you than I am. There is one point, however, which I think probably might not be dwelt upon, which seems to me to deserve especial attention, and that is the character of the water that is to be treated. I think the water itself deserves considerable study before the application of the copper can be made to

* U. S. Bureau of Plant Industry, Washington, D. C.

the best advantage. As Dr. Moore said to you at the beginning, referring to the susceptibility of different fish, we recognize that brook trout is probably the most sensitive fish, yet a few years ago one of the gentlemen connected with the Bureau of Fisheries told me of some experiments he had been carrying on in Wisconsin, and there, with water that is exceptionally hard and contains a rather unusually low amount of free carbonic acid, he was able to add a quantity of copper nearly a hundred times as great as that species of fish can ordinarily endure. I think this indicates that before a water can be treated successfully for algal growths, and before it is possible to treat it with safety to the fish, it is necessary not only to know the organism for which you are going to treat, but also the character of the water with which you are to deal.

I think this point is emphasized to some extent by the discrepancies between the papers of Mr. Ellms and of Mr. Clark, Mr. Ellms reporting the precipitation of the copper within twenty-four to forty-eight hours, depending on the character of the water, chiefly the organic matter contained. In Mr. Ellms' report it is stated, I believe, that the organic matter, even when he had rather a high quantity, was able to delay precipitation only about twenty-four hours, while Mr. Clark has just told you that in his experiments precipitation was sometimes delayed for more than twenty days.

New England water must be considered, therefore, more or less in a class by itself, because so far as our experience has gone, the reports of the western chemists are unanimous, I think, as to the comparatively rapid precipitation of the copper. We have only a few figures on eastern waters, and those of Mr. Clark are far and away the most extreme as to the length of time of the copper remaining in solution. If popular prejudice or scientific demand requires the study of the final disposition of the copper, or requires its complete elimination from the water, further research and perhaps additional processes will have to be inaugurated.

MR. EARLE B. PHELPS.* One of the most interesting observations of Dr. Moore and of Prof. Kraemer is the germicidal

* Massachusetts Institute of Technology, Boston, Mass.

effect of metallic copper upon typhoid infected water with which the copper may come in contact; and the suggestion has been made that the use of copper utensils, water-tanks, pitchers, and drinking goblets, might be of some service in protecting us against infection. The United States Geological Survey, through the Division of Hydro-Economics, has been carrrying out some studies upon the subject of the copper canteen, as to its availability for general army use and for use among the field parties of that bureau, and these investigations have been placed in my hands. Perhaps the results, so far as they are available, may be of interest at this time.

It is obviously impossible to use clean scoured copper canteens, and Professor Kraemer found it necessary, and other workers have always found it necessary, to keep their copper plates clean and scoured. I have attempted in my experiments to imitate as far as possible perfectly natural conditions, and I think none of us would consider cleaning with acid a feasible thing in the field or in the army. I started with clean copper canteens, cleaned with oxalic acid and very thoroughly rinsed. From that time on the canteens were not treated in any way, but they were allowed to accumulate any coating or tarnish which might form. The first series of experiments was made with Boston tap water, and following out the idea of using natural conditions I did not sterilize or filter the water, but took it just as it came from the tap. Of course I had to use large numbers of the typhoid germs in order to detect them with certainty at the conclusion of the experiment. The detection of the typhoid organisms was in every case checked up at the end of the experiment by the Widal test, which, of course, is the only sure criterion for the surviving germs.

Starting with the clean canteen and Boston tap water, the amount of copper dissolved in the first experiment was about two parts per million. In succeeding experiments the amount fell off, and at the eighth successive test it had reached a point less than a half of one part per million.

The efficiency of the canteen in destroying typhoid was considerable at the start, although nowise complete. I used large numbers of the organisms, about 100 000 per cubic centimeter, as nearly as I could hit it by dilution, and the final tests were

generally made at the end of twenty-four hours. At first the numbers were in the neighborbood of 6 to 10 per cubic centimeter. At the end of the series of experiments, or so far as we have gone with them, the numbers are in the neighborhood of 30 or 40, sometimes more. In only one case was there complete elimination of the typhoid organisms, and if I am not mistaken, the copper at that time amounted to about one part per million. It was after the fifth successive test.

Aside from the work with the Boston tap water, I have carried out similar experiments upon other waters, for I agree with the previous speaker that the quality or the chemical characteristic of the water is the essential factor. I have used both hard waters and turbid waters, and find that in both cases the efficiency is very much lessened. Calcium salts seemed to be especially harmful, and calcium carbonate the worst of all; the efficiency of the canteen upon a water high in calcium carbonate was almost nothing. Turbid waters also interfered seriously with the effect of the copper canteen upon the typhoid organisms. Mr. Sullivan of the Geological Survey, in attempting to explain the formation of copper deposits, has suggested a very interesting theoretical consideration in this connection. That is, that there is a law of chemistry, the so-called *mass law*, which demands that kaolin or common clay shall precipitate out the copper as silicate, a corresponding amount of alkaline salt being formed and dissolved.

I have also carried out a series of experiments on Boston tap water, using canteens which had been in use with these hard western waters, and found that the efficiency of the canteens was permanently lost and could not be recovered without carefully cleaning the canteen again. That is as far as I have gone. I have used three strains of typhoid organisms in attempting to find some relation between the age of the organism and the efficiency of the canteen upon it, but so far the differences are too slight to notice. The three strains had been on artificial media about two years, one year, and one month, respectively, and, as I say, the differences in the effect upon the three strains were not noticeable.

Mr. Robert S. Weston.* Many bodies of water which are not used as sources of water supply, but which are used for pleasure, ornament, or for furnishing ice, often suffer from disagreeable growths of odoriferous algæ. This has been especially noted in New England, because of the prolonged drought during the present summer. Many of the lakes and ponds which ordinarily are inoffensive have produced such enormous growths of *Anabæna* and other organisms as to be exceedingly offensive to the inhabitants of their shores.

Such was the case at Newton Centre, Mass., where the waters of Crystal Lake were so offensive during August as in many cases to cause the dwellers on the shores of the lake to move away. An examination of the water on August 11 showed it to be very turbid with a growth of *Anabæna*. These organisms produced the usual objectionable "pigpen" odor.

In a report to Mr. H. A. Stone, secretary of the Newton Board of Health, the writer advised the treatment of the reservoir with copper sulphate in the proportion of one part of the chemical to four million of the water. This procedure was carried out under the direction of Mr. Stone, with the coöperation of the city engineer, Mr. I. T. Farnham.

The lake, which has an area of 31 acres and a capacity of about 142 650 000 gallons, was divided into seventy sections, and each section was treated separately with its proportionate weight of chemical. Allowance was made for the variation in depth of the pond.

The chemical, contained in sacks, was applied in the customary way by trailing it astern of a boat. Two sacks were used alternately, the one in use being kept more than two thirds full at all times.

The chemical was applied on Friday, August 18. An improvement in the appearance of the water was noticeable in three hours. After two days the water contained about 25 per cent. as many *Anabæna* as before treatment. On the 21st the improvement was very marked, and on the following Wednesday, the 23d, the water was of excellent appearance and free from odor, in which condition it has remained until the present date, September 9. The pond contains an abundance of bass and perch,

*Sanitary Expert, Boston, Mass.

none of which were killed by the treatment. The only fish killed were about a peck of small fingerlings or minnows. The cost of the treatment was less than fifty dollars.

While it is true, as Mr. Goodnough states, that there was a growth of *Scenedesmus* after the application of the copper sulphate, this organism was unobjectionable, while the odoriferous *Anabæna* were destroyed.

It would seem, therefore, that from the above experience copper sulphate has a field of usefulness in similar cases where a nuisance is to be avoided. This treatment should be conducted with extreme care, as inefficient distribution of the chemical will certainly cause the death of many fish. The writer does not believe that the use of strong concentrations of copper sulphate is feasible in such cases, as it is extremely unwise to destroy all the objectionable organisms in a pond if at the same time large numbers of fish must be killed, as has been the experience in other cases.

The writer hopes for an opportunity to apply copper solution in the form of a spray, using for this purpose such an atomizer as is used for spraying trees and crops. The better the distribution, the greater the concentration which can be applied without destroying the fish.

In conclusion, the writer may say that he believes copper sulphate to be an efficient tool in proper hands, but not one which can be put to all sorts of uses.

DR. GEORGE A. SOPER.* The copper sulphate method has been advanced as a means of putting an immediate check to typhoid epidemics due to infected water supplies, and it is this point to which I will restrict my discussion. The official statement of Messrs. Moore and Kellerman, to which I refer,† is contained in one of the last bulletins of the Department of Agriculture, and is as follows:

"Treatment with copper sulphate is an effective and practicable means of sterilizing water polluted with certain pathogenic bacteria, and as an emergency method is applicable to both household and municipal conditions. It should prove particu-

*Consulting Sanitary Engineer, New York City.

† Bulletin No. 76, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905, pp. 38–39.

larly useful in very large water supplies accidentally or suddenly contaminated with typhoid bacilli and not provided with any adequate means of purification. Under such circumstances the case becomes not one of pure water versus water containing copper sulphate, but of sterile water containing an amount of copper not dangerous to health versus water and typhoid bacilli. The method formerly suggested for treating a reservoir would undoubtedly be advisable in special cases of unusually great contamination when the water contained an abnormal amount of organic matter, but *in general an epidemic could be controlled and quickly eradicated by a solution much weaker than the 1 to 100 000* listed as necessary for complete sterilization within twelve hours. *One to 2 000 000 is sufficient in most cases*, and even less than this quantity of copper is of decided benefit in certain kinds of water." (Italics mine.)

The experiments which have been made with copper sulphate in the destruction of typhoid fever germs have been made in the laboratory under conditions which should show the very best results for the copper sulphate treatment, yet there appears to be a good deal of uncertainty as to the amount necessary in order to destroy the germs. For a disinfectant to be reliable, we must know with accuracy how much to apply in order that all of the dangerous bacteria may be destroyed. As has been well pointed out, it will not do to dose the public water supply with chemicals in the mere hope of doing some good. By disinfection we seek to destroy all the offensive organisms, and when we attempt to disinfect a water supply, the public depends upon us to accomplish this result. Half-way measures in disinfection are not possible; the result must be absolute or it is misleading.

From experiments which have been mentioned here, and which have been paralleled by some which I had an opportunity to make at the College of Physicians and Surgeons in New York, about eighteen months ago, it appears that we are not by any means certain that all the typhoid fever germs in a water, even in a laboratory, will be destroyed by one part of copper sulphate in 75 000; and yet that dose, if applied to the filtered Croton water, will produce such an opalescent appearance and blue color that people will not drink it.

The technique of the laboratory experiments which have been

reported seems to me to afford incomplete evidence that typhoid fever germs will be destroyed even in a concentration of copper sulphate as high as 1 part in 25 000. In 1902, Schüder* published a critical study of various methods which had been proposed for sterilizing water by means of chemicals, and in this he reviewed the results of experiments of other investigators. Schüder found that the common plate method did not afford certain evidence of disinfection; that there were apt to be germs left over from the process or surviving in a feeble condition on the plates which he could find by a more delicate process. His improved procedure was in substance as follows: After allowing the disinfectant to act for the time which was thought to be sufficient for sterilization, the excess of disinfection was neutralized, and enough soda added to the water to produce an ordinary alkaline reaction. The entire sample of water, amounting to many hundred cubic centimeters, was then divided up into flasks of 100 to 200 cubic centimeters each, and to each of these was added enough concentrated peptone salt solution to form a 1 per cent. peptone salt culture medium. The flasks were then incubated for thirty-seven hours at 37° C. They were finally examined for typhoid bacilli by means of the Conradi Dreglaski method and the colonies so developed were fished and tested by the agglutination test. Schüder's conclusion was that results obtained in any less delicate way were certain to be unreliable and misleading.

There is another consideration which indicates that the laboratory experiments, even granting that they have been accurate, which I think they have not, will not apply with any certainty to conditions of actual practice. Most, if not all, of the experiments have been made with typhoid germs which have been cultivated in bouillon. The organisms so cultivated are certain to be evenly distributed through the water and sterilized. This is not a condition known to exist in nature. It is not likely that the typhoid bacilli which produce an epidemic in a water supply are separated evenly throughout the water. It is far more reasonable to believe that they are usually aggregated in clumps or small masses of feces and other matter. This being so, the copper sulphate would have to penetrate those masses in order to be

* Zeit. f. Hyg., 1902, xxxix, p. 379.

effective in destroying the germs. There have been no experiments made which indicate that copper sulphate has any efficiency in this particular direction.

Two opportunities have occurred in my practice to use a chemical disinfectant to sterilize a water supply in order to check an epidemic. One was at Ithaca, N. Y.; this was an epidemic, it will be remembered, of about thirteen hundred cases. I had been called on to act as expert by the New York State Department of Health to do what was possible to stop the progress of the disease. It was proposed by L. M. Dennis, professor of chemistry at Cornell University, that a chemical be applied to the water in the hope of sterilizing not only the water but the distribution pipes of the water works and the reservoir. The disinfectant proposed was permanganate of potash. The amount required was carefully estimated from experiments made in the laboratory and the proposer of the process spent much pains in order to secure a sufficient supply of pure chemical for use. It was intended that the permanganate should be added in a solution at the pumps or reservoir and that the hydrants and faucets throughout the city should be allowed to run open until the characteristic pink color of the permanganate should appear. The arguments on both sides of the question were very carefully gone over by Professor Dennis and myself, and after considering the matter fully, I concluded that it was not desirable to attempt disinfecting the water supply in this way, but before taking the responsibility of deciding against an attempt, which, if successful, would have been so beneficent, I asked my friends, Messrs. George W. Fuller and Allen Hazen, who happened to be at Ithaca at that time, to confer on the subject. We met with Professor Dennis, the subject was fully discussed, and the disinfection of the water supply was thought by them to be an unwise and unpromising project to attempt.

Again at Watertown, N. Y., in 1905, where I acted as consulting sanitary expert to the city board of health in its efforts to suppress a typhoid epidemic of about six hundred cases, the use of a disinfectant to sterilize the water supply was carefully considered. The preliminary notices of the supposed value of copper sulphate were being published in the press while the epidemic was in progress, and I was urged by many persons to give it a

trial. I decided against the use of copper sulphate in this instance as being uncertain, untried, experimental, and unwarranted in view of the possibilities for mischief and misconception which it seemed to contain.

It is not necessary for me to go into the technical details which led me to reject the use of copper sulphate on two such important occasions. It can readily be appreciated, I think, by the members of this association that in order to reach every part of the material to be disinfected, it would be necessary to apply the disinfectant in very large quantities at first and that there would be extreme difficulty in making certain that it would penetrate to the various parts of the distribution system wherein bacteria might lurk. Too little is known about the behavior of the typhoid bacillus in the piping system of the water supply. We do not know the part played by bacteria in dead ends, among sediments and accumulations of organic matter such as exist in all water works, and there is need of more scientific information concerning the longevity of the germ in reservoirs.

It seems not improbable that the infectious matter which produces the great spring epidemics, which are the severest we have, is usually taken into the water works system at one time, perhaps within an hour or even a few minutes, and that it gains a lodgment there, developing and multiplying and giving off bacilli to the water which runs through the pipes for many weeks, if not months. In such epidemics as those of Butler, Ithaca, and Watertown, it usually is from ten days to three weeks from the freshet in the creek or river, when the germs are taken into the distribution system, before many cases of typhoid fever among the consumers of the water are discovered. It is usually between three and six weeks afterward that the maximum number of cases per day occur. It is usually betweeen two and three and one-half months before the disease ceases to be epidemic. There is no doubt that, even after these epidemics, cases of genuine typhoid have been contracted from the water supply. Theoretically, the supplies should have been emptied of their original water and refilled with fresh water by the natural process of supply and consumption within two or three days. It would seem inconceivable that this and the process of flushing the mains which was used in these

cases should not have removed all of the organisms. Yet against this reason the germs seem to have persisted.

To check an epidemic coming from a water supply by the use of chemical disinfectants applied to the water as it enters the pipes would require an exceedingly efficient process, far more so, I think, than has been demonstrated so far for the copper sulphate treatment. We know nothing whatsoever as to the certainty of the behavior of copper sulphate under the conditions of actual practice.

MR. ALLEN HAZEN.* The general discussion has been so excellent and has brought out so many points that I do not feel that I can add to it. I wish to mention only an historical point.

I think that the idea of using copper sulphate for destroying algæ in public water supplies is entirely due to Dr. Moore, and that he should receive all credit for it. But copper sulphate was suggested very seriously a long time ago in Germany for treating polluted water supplies. It was directly after the epidemic of cholera in Hamburg, in 1892, when exhaustive studies with different metallic salts were made by a German chemist, Kröhnke. This led him to recommend the use of copper sulphate in handling typhoid and cholera-infected water; but the German engineers, some of whom I knew at the time, were not willing to take the responsibility of giving their people copper in the quantity necessary to be effective in this way, and they thus anticipated that part of our present discussion.

MR. GEORGE A. JOHNSON. I have only two points to which to refer, Mr. President. One of them has to do with Dr. Soper's remarks regarding the value of the experimental work which has been done in connection with these copper sulphate studies. It appears to me that their general value is very great, because in the laboratory conditions are kept under careful control, and such results as are obtained represent the extreme influence which this chemical can have on the specific organisms studied. Of course, as Dr. Soper has said, the results obtained by experimental work in the laboratory only have an indirect applicability to many practical propositions on a large scale.

* Consulting Engineer, New York City.

The other point to which I should like to refer has to do with the use of copper sulphate in connection with unfiltered water supplies. Experiments of such a nature were conducted by the Health Officer, Dr. McKendree Smith, at Columbus last year, and the results are set forth in a prominent manner in the last publications of Messrs. Moore and Kellerman. The conditions surrounding Dr. Smith's experiments were as follows:

The Scioto River, which serves as the source of a portion of the water supply of Columbus, is sometimes badly polluted. At the time of Dr. Smith's experiments it was at very low stage, being not much more than a succession of pools above the city. Copper sulphate was added intermittently to the Scioto water at or near the intake in quantities never in excess of one part in 1 500 000. The city of Columbus is on a direct pumping system, and, therefore, no very considerable period of time was possible for contact of the chemical with the water after its application. The longest period of contact which could have been obtained under any circumstances could not have amounted to more than about six hours.

There was one feature in connection with these experiments of Dr. Smith which as yet, I think, has never been brought out, and that has reference to the fact that the application of the copper sulphate to the river water was begun at the commencement of a prolonged drought of about four and one-half months, throughout which its use was intermittently continued, and then stopped by order of the city authorities some ten days after a succession of heavy rains. Almost immediately following the discontinuance of the chemical treatment the cases of typhoid fever began to increase. It has been claimed that the sudden outbreak of typhoid fever at this time was due to the fact that the copper sulphate treatment had been discontinued. From the following tabulated statement it appears to me that inasmuch as the treatment was intermittent at best and never extended to the entire city water supply, and as the chemical was never added in quantities in excess of one part in 1 500 000, and as a period of contact of only a few hours was possible, the increase in typhoid fever cases following the breaking of the drought was due to the flushing into the river and into the city mains of pol-

luting matter which had been accumulating for months, rather than to the discontinuance of the copper sulphate treatment. In other words, there is no sound evidence to show that there was much infection during the autumn for the copper sulphate to have destroyed, or that the treatment would have been as effective as claimed if it had been longer continued after the appearance of the belated fall rains.

RELATION BETWEEN THE NUMBER OF TYPHOID FEVER CASES IN COLUMBUS AND THE AMOUNT OF RAINFALL.

Month.	Number of Cases.	Total Precipitation for the Month. (Inches.)
June, 1904	24	2.78
July	23	2.27
August	52*	3.18
September	16	0.83
October	16	0.97
November	8	0.18
December	4	3.63†
January, 1905	91‡	1.25
February	376	1.57
March (to 27th)	279	1.87

MR. P. A. MAIGNEN.§ The question of sterilization of water by chemicals is not new. As far back as 1900, the speaker and Mr. Burlureaux, in Paris, found and published the fact that "hard" water, treated chemically for the elimination of the dissolved lime salts or "softened," was at the same time sterilized.

All chemical reactions in water interfere with the growth of bacteria. Almost any kind of chemical, added to the water in sufficient quantity, is capable of sterilizing.

We owe to Dr. Moore considerable credit for having brought to the front the question of the chemical sterilization of water and caused it to be taken into consideration, at a time when the chemical treatment of water in general, and with alum in particular, was under the ban of condemnation by the medical profession and the people generally.

* Copper sulphate used after August 19.
† Copper sulphate discontinued January 5.
‡ Between the dates December 24–27, 1904, the total rainfall amounted to 2.93 inches.
§ Filtration Engineer, Philadelphia, Pa.

We also owe to Dr. Kellerman a practical suggestion for the avoidance of the dangers presented by the chemical treatment of water. His suggestion amounts in effect to this, — that you may use any and all the chemicals you please, such as potassium permanganate or sulphate of copper (the latter being one of the strongest antiseptics known) in any quantity, provided you take care to remove all traces of chemical that might remain in the water after treatment. This removal can be obtained by secondary chemical reactions or by filtration through charcoal.

The speaker cannot help thinking that it is absurd to attempt to sterilize a whole lake or all the water supply of a large city. What is the use of sterilizing by copper, or otherwise, the water needed for elevators, gardens, laundries, boilers, street sprinkling, carriage washing, or putting out fires?

Absolute sterilization must necessarily be an expensive operation and should be confined to the water used for domestic purposes. In Paris there are two sets of water pipes, one set conveying spring and filtered water for domestic use, which is sold at twenty-four cents per thousand gallons, and another distributing plain river water intended for sprinkling and industrial purposes. The latter is sold at twelve cents per thousand gallons.

The speaker ventures to suggest the establishment, wherever practicable, of a double canalization; one to convey sterilized water for drinking purposes and another to supply plain water or water freed from mud by some economical system of filtration for industrial and municipal requirements. The speaker further desires to be understood as being favorable to the cause of chemical sterilization, provided it be carried out scientifically, economically, and with sufficient safeguards.

Mr. George C. Whipple.* After what has been said I feel that I have little to add to the discussion. My own experience in the practical use of copper has been limited. Perhaps I might mention one instance in my experience which is slightly different from what has been mentioned. The well of a certain farmer in New Hampshire had, for a number of years, been so bad that

* Consulting Engineer, New York City.

it could not be used, either for drinking or for watering the stock. The water was turbid, dark colored, and very offensive in odor. It had been so for a number of years, although several attempts had been made to clean out the well. Microscopical examination showed that the water contained a heavy growth of *Crenothrix manganifera*. I gave instructions to the farmer to dose this well with copper, let the water stand for several days, and then clean out the well thoroughly, washing off all the stones and removing all the sediment at the bottom. He followed my instructions and the treatment was entirely successful. After the well had been thoroughly pumped out the water became clear and sparkling and the supply is now perfectly satisfactory. I cannot state just how much copper was used, as I do not know just how much water there was in the well at the time when he made the application. The amount which I intended to use was one part in two million, and I think that this figure may be taken as approximately correct.

This case is interesting, as it shows the action of copper upon one of a group of microscopic organisms hitherto not experimented with to any extent.

Mr. Hazen has referred to the work which was done by Kröhnke a few years ago. Mr. Andrew Mayer, Jr., the chemist of our laboratory, has recently translated this paper, and as it contains many facts of interest I think that it will be well to incorporate his translation in this discussion in order that it may be available for convenient reference.

Mr. Mayer has also made in our laboratory a number of experiments upon certain details of the reactions which take place when copper is added to water. The effect of carbonic acid upon the solubility of the basic copper carbonate was one of the matters studied. It was found that the basic carbonate is soluble in carbonic acid free water to the extent of 0.4 parts per million, expressed as copper sulphate. The addition of carbonic acid increases the solubility of the basic carbonate very greatly, as shown by the following table:

Free Carbonic Acid. Parts per Million.	Solubility of Basic Copper Carbonate Expressed in Terms of Parts per Million of Copper Sulphate.
0	0.4
1	4
2	9
3	12
4	15
5	20
10	35
20	52
30	66
40	78
50	90
100	125

When both aluminum sulphate and copper sulphate were added to water, with enough sodium carbonate to take up all of the free carbonic acid formed by the reaction, it was found that copper sulphate was removed to the limit of solubility of the basic carbonate in water free of carbonic acid, namely, about 0.4 parts per million.

It was found further that different methods of preparing the basic copper carbonate gave different solubility results. In some cases the solubility in carbonic acid free water was as low as 0.2 parts per million.

Suggestions for the Improvement and Sterilization of Surface Water by Chemical Methods, with Special Reference to the Elbe Water at Hamburg.*

BY B. KRÖHNKE.†

[ABSTRACT.]

* * * * *

There yet remains, for the purpose of purification, chemical disinfection; and this method has the great advantage over filtration that it affects in the same way all portions of the water treated. The disinfecting medium must be sufficiently powerful to kill, with complete certainty, at least the pathogenic germs, in a

*In Journal für Gasbeleuchtung und Wasserversorgung, v. 36 (1893), p. 513.
†Translated by Andrew Mayer, Jr., chemist with Hazen & Whipple, New York.

reasonably short time, and also, if possible, all the other germs occurring in water, although this last condition is of less importance. There are, indeed, a large number of chemical reagents which fulfill this condition; a great number of them, however, are organic in nature, and although sufficiently powerful to completely kill all germs, even the best of them are open to the objection that they cannot be removed from the water again, economically or easily, and are thus out of the question for use with drinking water. It seems as though we were confined, for this purpose, to the inorganic poisons, and I have made a careful study of these, with reference to their use as disinfectants and with special reference to their easy and certain removal from water after their action has been completed. In looking over the inorganic compounds which could be used here, it seems to me that, in general, those elements are most poisonous for the living organism which have a great affinity for sulphur, and whose sulphides offer most resistance to decomposition by other compounds. There is really no absolute scale for the degree of toxicity of a substance. Poisons act in entirely different ways upon different organisms. There are, of course, a large number of elements and compounds which, by reason of their caustic qualities alone, act in a very poisonous manner and can destroy organic life, but for use here they are out of the question.

I confine myself entirely to those which are inimical to the inmost physiological life processes and can be considered septic or narcotic poisons. First in the scale of toxicity and of affinity for sulphur stand the alkali metals, which, in a strict sense, can hardly be considered poisonous. Their sulphides are easily soluble in water and are decomposed by very weak acids, even by carbonic acid. Then come the alkali earth metals, some of which are to a certain extent poisonous and whose sulphides are more insoluble than those mentioned above. Then come those metals whose sulphides are entirely insoluble in water and require fairly strong acids to effect decomposition. Noteworthy among these are iron, manganese, zinc, cobalt, nickel, etc. Finally comes that group of compounds whose sulphides are insoluble, not only in water, but also in diluted strong acids, that is to say, those acids which do not exercise any oxidizing action. To this group

belong, among others, bismuth, tin, antimony, arsenic, copper, silver, lead, mercury, etc., whose compounds are all poisonous, excepting only those which are absolutely insoluble in water, or in the juices of the living organism. Among all metals without exception, copper, when in the form of cuprous salts, for instance, cuprous chloride, stands first in affinity for sulphur. Copper in the form of cupric salts, on the contrary, has a much weaker affinity for sulphur and the corresponding sulphide is much less stable. Cupric chloride is also less poisonous than cuprous chloride. What relation this affinity for sulphur bears to the functions of life is another question. The albuminoids and the proteins probably play the leading parts in the living protoplasm, but concerning the chemical constitution of these bodies there is less known than of any other group in organic chemistry. Only this much is certain, they all contain sulphur as an essential constituent, but whether the copper, in the form of cuprous salt, produces decomposition by removing sulphur from the atomic complex of protein, and acts as a poison in this way, either directly or through the by-products formed, must remain for the present a very uncertain hypothesis. At any rate the apparent systematic parallel of the affinity of metals for sulphur on the one hand, and the degree of toxicity on the other, suggests the testing of cuprous chloride as a sterilizing medium, and the results apparently justify the above hypothesis. Cuprous chloride has also, for the purpose in question, still other valuable properties, viz., it can be very easily prepared, as I shall show later; it can be easily and certainly separated out again after use; its higher degree of toxicity disappears upon simple contact with the air by reason of its transformation into cupric chloride; the copper can be obtained again easily without loss; and, finally, it is not decomposed, like cupric chloride and the other cupric salts, by calcium bicarbonate, which is present in every surface water. For this very reason, apart from their slighter effectiveness as disinfecting media, the cupric compounds have less practical value for this work. They would have to be used in larger quantities, in order to act as desired, because they are, as has been stated, decomposed by the calcium bicarbonate present in water and thus precipitated and rendered ineffective.

Copper sulphate, it is true, is not immediately precipitated in the cold, but gradually, and in proportion as the carbon dioxide formed by the reaction escapes, for instance, through warming or through lessening of the air pressure. It is, however, gradually decomposed and changed to copper carbonate, which remains partially dissolved in the free carbonic acid for some time, so that even after twenty-four hours traces of copper can be found in the filtered water, even after the solution has become colorless. Cupric chloride, however, is more quickly decomposed by calcium bicarbonate than is the sulphate, and when the latter comes into contact with sodium chloride, which is always present in surface water, cupric chloride is formed by double decomposition. In order to avoid the decomposition of cupric chloride, the entire lime content of a water must previously be neutralized by sulphuric acid, or some other similar reagent, for instance, ferrous sulphate, or, better, by both combined, as the basic ferric sulphate which precipitates carries down part of the sulphur trioxide of the ferrous sulphate. In fact, by the addition of 1.2 gm. of concentrated sulphuric acid (1.83 specific gravity), 0.6 gm. copper sulphate and 0.6 gm. ferrous sulphate to 10 liters of water, I obtained, after the mixture had stood eighteen hours, a water completely free from germs, which developed no colonies of bacteria on nutrient gelatine after standing six days at room temperature. Upon subsequently adding 0.7 gm. of quicklime the water was rendered completely neutral and colorless and also free from copper, iron, and arsenic. The precipitate formed, when air dried, weighed 2.95 gm. or almost 3 kilograms per cubic meter of water. Cuprous chloride, however, is even more effective than cupric chloride or copper sulphate, is not decomposed by calcium bicarbonate as are the cupric salts, and, although soluble with difficulty in water, is still sufficiently so for action upon germs. When added in small quantities to surface water containing lime the mixture is almost absolutely clear, and the filtrate therefrom, even when diluted a million times, still shows a reaction for copper with potassium ferro-cyanide as well as with hydrogen sulphide. A very slight turbidity occurs after a considerable time, as a result of oxidation by the air contained in the water.

Cuprous chloride dissolves very readily, to the extent of about

36%, in hot, concentrated sodium chloride solution, but separates out again, upon cooling, in the form of small white crystals, leaving still in solution from 4 to 7 per cent. according to the temperature. Upon the addition of pure water, free from air, the larger part is thrown out as a heavy white crystalline precipitate; if, however, the water contains air, or organic matter, or if it has absorbed oxygen from the air and is, at the same time, neutral, containing no free acid, the cuprous chloride is at first retained in varying amount. Then there forms, gradually, a white precipitate which, after a short time, however, changes color and becomes a Pomeranian yellow. The presence of a little free acid, in the absence of organic matter, prevents this change in color. An entirely neutral solution of cuprous chloride in sodium chloride absorbs oxygen when exposed to the air, forming a green surface film of oxy-chloride with simultaneous formation of cupric chloride; if free acid is present this color is at first brown, which, upon continued action of the air, becomes a pure green. On account of this action of air upon cuprous chloride one must avoid as much as possible any strong agitation when mixing it with water, and must effect solution as rapidly as possibly by simple rotation. If this precaution is observed, especially with dilute solutions, only a very small portion remains directly in contact with air, and there is obtained a neutral cuprous chloride solution oxidized only by the air already contained in the water. This oxidation proceeds very gradually in the cold; not rapidly, as is the case with ammoniacal solution of cuprous oxide. That portion of the cuprous chloride which is thus oxidized reacts with any calcium bicarbonate present, and is gradually thrown down as a light blue-green precipitate of basic copper carbonate.

For the experiments on killing germs and the disinfection of Elbe water, I used a solution of cuprous chloride in sodium chloride, which, for convenience in calculation, contained almost exactly 1 per cent. metallic copper. In order to keep this solution entirely clear and colorless, it is necessary to render it slightly acid with a few drops of hydrochloric or sulphuric acid and place in it a coil of copper wire, or some strips of copper foil. The flask containing the solution should be immediately stoppered after using. Every time the flask is opened a little copper is dissolved as a

result of oxidation by the air admitted. For very precise experiments it is, therefore, necessary to frequently analyze the solution, to control the amount of copper used, or the necessary amount of solution must be drawn off and its volume replaced by carbon dioxide, or some other indifferent gas. I added 7.2 gm. of such a solution, which contained exactly 1.08 per cent. of metallic copper, hence .078 gm. of copper to 12 liters of Elbe water. This is in the proportion of one part of copper to 155 000 parts of water. I divided the mixture among 12 flasks which contained one liter each, and let them stand loosely covered, in order to prevent, as far, as possible, the entrance of germs from the air. The solution was at first absolutely clear. Later there appeared a very slight opalescence. Portions, when taken out and filtered until clear, slightly acidified, and mixed with potassium ferrocyanide, showed a rose-red color in thick layers, proving that copper was yet in solution, and this reaction persisted even after standing six days. The test for copper with ammonia, on the contrary, gave no result. After standing fifteen hours several portions were withdrawn, with the usual precautions, and plated out on gelatine. Several portions of the plain Elbe water, from which the mixture had been made, were also plated at the same time for comparison. I feared that the very slight trace of copper still in solution might prevent the development of the germs present when the mixture was plated out on nutrient gelatine, although in all probability the copper would be rendered insoluble by the alkaline reaction of the gelatine. Accordingly I added, to one flask of the mixture, clear lime water (containing 1-800 of its weight in lime) until a filtered portion gave no further reaction for copper. According to calculation, and taking into account the slight acid reaction of the cuprous chloride solution, one half as much lime as the copper added, that is, .04 gm. of lime or 32 gm. of lime water, should be sufficient for 12 liters of the mixture. The test portions, when filtered, still contained copper, however, even after the addition of 64 gm. or 96 gm. of lime water, but were completely free from copper after the addition of 120 gm. of lime water, which corresponds to one part of lime per 80 000 parts of water. The excess over the calculated amount is caused by the calcium bicarbonate present. After the precipitate formed,

upon the addition of the lime water, had settled out, 1 cc. was taken and plated out. Even after five days those plates made from the mixture, and also those made from the mixture to which lime had been added, still remained sterile, except for some isolated colonies, for the most part mould-growths, which should be considered as due to unavoidable errors of method. On the contrary, the control tests with the original Elbe water showed, after two days, 12 500 germs per cubic centimeter. In earlier experiments I obtained as much as 100 000 germs; the present (Jan. 18) marked decrease is due to the extreme cold and the freezing of the upper Elbe. Cultures plated from the mixture after it had stood twenty-four and thirty-six hours, respectively, were also sterile.

The filtered water obtained after treatment with lime was entirely colorless, completely free from copper and iron, neutral, and had, as all agree, a very good flavor, without the peculiar flat taste of Elbe water which has been boiled and then filtered. The precipitate containing copper, obtained from the entire 12 liters, weighed when air-dried .14 gm.; when dissolved and titrated in ammoniacal solution with potassium cyanide, it showed exactly the same amount of copper as had been added. Besides this, it contained the inorganic settlings and a considerable amount of organic matter which had been coagulated and precipitated with the copper. It contained, however, no carbonate of calcium. As was to be expected, such a slight precipitate settles very slowly from so much liquid, so that the water did not become sufficiently clear until it had stood somewhat longer than twenty-four hours. The precipitation is, however, much hastened by the addition of a little ferrous sulphate, in proportion of 1-50 000, before adding the lime. The amount of lime added must be correspondingly increased from 1-80 000 to 1-50 000. The better the precipitate coagulates the quicker the water clears; after repeating the operation several times and saving the precipitate, the further addition of ferrous sulphate would be no longer necessary.

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The procedure for the purification of water with or without the addition of sulphide would be carried out in the following way: The water to be purified is drawn into a basin and stirred so rapidly that it will completely mix with the cuprous chloride without

absorbing too much oxygen from the air. The stirring might be done by a central mixer made of wood and copper. It should contain no iron. Then the cuprous chloride solution is allowed to flow in gradually and after it has been thoroughly mixed with the water, the mixture is allowed to rest 6 to 24 hours, as desired. The length of time necessary for this stage of the process depends upon the relative amount of cuprous chloride used, and is also governed by the extent of purification desired. If one is satisfied to leave a few harmless water bacteria, after killing all the pathogenic germs, one part of copper, in the form of cuprous chloride, per 1 000 000 parts of water, with a digestion of twenty-four hours, will be sufficient. This is in the proportion of one kilogram of copper per 1 000 cubic meters of water. It should also be remembered that after the settling of the precipitate the water is filtered and the small number of germs remaining still further reduced. If, however, it is desired to completely destroy all the germs in a water, five times as much copper must be used, or one kilogram of copper per 200 cubic meters of water, if the latter is of medium quality.

The water thus disinfected is run into a second basin and the separation of the copper is completed here. For this purpose there should be added the necessary amount of the mixture of iron sulphide and lime. The liquid should be then thoroughly agitated until a test portion shows that all the copper has been precipitated. One hour will be required, as a rule. The water should then be allowed to stand until sufficiently clear.

If it is desired, however, to remove the copper by the method first described, these reagents should be added in the following order:

1. Sodium sulphide (or calcium sulphide, or barium sulphide), either dissolved or as a powder.
2. Ferrous sulphate, dissolved in previously disinfected water.
3. Quicklime, either as lumps, which can be placed in a cage of iron and submerged in the water, or as milk of lime.

The mixture should then be strongly stirred from two to three hours and allowed to stand until the precipitate formed has settled and the clear water can be drawn off. The first settling will take place somewhat slowly and require at least twenty-four hours.

Later, however, when more precipitate is present, considerably less time will be required. The water, when drawn off gradually and at a sufficient distance from the bottom, contains none of the precipitate and is then ready for use. It is clear, neutral and free from copper and arsenic, even though the sulphuric acid used for dissolving the copper contained arsenic.

* * * * *

Objection will be made to the use of copper in water purification, since its compounds are more or less poisonous for men and animals. I shall accordingly endeavor to settle any doubt on this subject. Many substances in large doses act as poisons, but do not exert such effect in very dilute solutions. We daily consume with our food more or less matter which in large amount would act as poison. For instance, copper is normally found in the human body, even to an extent of 2 gm. Copper in the proportion of one part to one million of water as used for disinfection is equivalent to 1 gm. per cubic meter. This is only one half of the amount which the human body may already contain. During the process of disinfection, however, at least $\frac{9}{10}$ of this is rendered insoluble and separated out. There remains dissolved, therefore, per cubic meter of water, only $\frac{1}{10}$ gm. of copper. This is the maximum residual amount, and, at that, does not exist in the more poisonous form of cuprous chloride, but in the form of cupric chloride, as a result of oxidation by the air. Even if there were no further treatment with sodium sulphide, ferrous sulphate and lime, one would have to drink 20 cu. m., or 20 000 liters of water in order to take in as much copper as is already present in the system. At the rate of two liters per day this would require ten thousand days, or almost thirty years. The presence of even such a small amount of copper in the water, after treatment, is assumed only for the sake of argument, to overcome any prejudice which the public may have against this use of copper. As a matter of fact, the presence of copper would be absolutely impossible, even if the above precautions, that is, treatment with sodium sulphide, etc., were only partially observed. The danger to life and health from a far more dangerous cause, viz., the bacteria of water, merits much more earnest attention.

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TABLE A. TYPHOID BACILLI (1 cc. used for plating).

Mixture made with Cu_2Cl_2 sol. containing 1% Cu.	After Addition of Cu_2Cl_2.			After Precipitation.		From the Precipitate.
	7 hours.	12 hours.	23 hours.	24 hours.	48 hours.	
I.	10 colonies	5 colonies	3 colonies	7 colonies	2 colonies	About 200 colonies. Many Wurzel bacilli. Majority liquefiers, some gray
1 000 cc. water						
3 cc. Cu_2Cl_2	4 gray liquefiers	2 gray liquefiers	2 gray liquefiers	1 Wurzel bacillus 1 gray liquefier		
Dilution 1–333 333	No typhoid	No typhoid	No typhoid	No typhoid	No typhoid	No typhoid
II.	8 colonies	5 colonies	8 colonies	40 colonies		
1 000 cc. water	2 gray liquefiers		3 gray liquefiers			
2.5 cc. Cu_2Cl_2		1 Wurzel bacillus	3 Wurzel bacilli	2 surface		Like I
Dilution 1–400 000	2 Wurzel bacilli		2 surface non-motile		Sterile	
	No typhoid	No typhoid	No typhoid	No typhoid		
III.	3 colonies	7 colonies 2 Wurzel bacilli 2 round	2 colonies		2 colonies	
1 000 cc. water						
2.22 cc. Cu_2Cl_2	1 Wurzel bacillus		1 Wurzel bacillus			
Dilution 1–450 000	1 gray liquefier	2 gray liquefiers 1 yellow	1 light liquefier	Sterile		Like I
	No typhoid	No typhoid	No typhoid		No typhoid	
IV.	7 colonies	5 colonies	4 colonies	25 colonies	About 1 000 colonies	
1 000 cc. water						
2 cc. Cu_2Cl_2	3 gray liquefiers	1 Wurzel bacillus 1 gray liquefier	1 Wurzel bacillus	10 gray liquefiers 2 surface	Majority liquefiers	Liquefied
Dilution 1–500 000	No typhoid	No typhoid	No typhoid	No typhoid	No typhoid	
V.	8 colonies	11 colonies 2 Wurzel bacilli	8 colonies	60 colonies	Countless colonies	
1 000 cc. water						
1 cc. Cu_2Cl_2	3 gray liquefiers 1 round	5 surface, which did not grow like typhoid	1 Wurzel bacillus	30 gray liquefiers	Many liquefiers	Liquefied
Dilution 1–1 000 000	No typhoid	No typhoid	No typhoid	No typhoid	No typhoid	

TABLE B. CHOLERA BACILLI.

500 cc. sterilized distilled water added to	Plated with 1 cc. water, after period of				Remarks.
	6 hours.	12 hours.	24 hours.	48 hours.	
I. 10 cc. cholera culture in 1% Pepton solution + 0.5 cc. 1% Cu_2Cl_2 solution 1-100 000	Many cholera colonies visible after two days standing	Sterile	Sterile	Sterile	After the addition of the Cu_2Cl_2 solution the water assumed a blue color, because it was rendered alkaline by the Pepton solution. The color was discharged by 1 drop H_2SO_4.
II. 3 cc. aqueous emulsion of cholera culture + 0.33 cc. 1% Cu_2Cl_2 solution 1-150 000	Isolated cholera colonies appeared in four days. The movement of the bacilli, as seen in hanging drop, was very feeble	Sterile	Sterile	Sterile	
III. 3 cc. aqueous emulsion of cholera culture +0.25 cc. Cu_2Cl_2 solution 1-200 000	Many colonies after standing three days	Sterile	Sterile	Sterile	
IV. 3 cc. aqueous emulsion of cholera culture + 0.2 cc. Cu_2Cl_2 solution 1-250 000	Sterile	Sterile	Sterile	Sterile	

MR. H. W. CLARK. I just want to mention one or two things in regard to the methods used for the determination of copper, which were suggested by what Dr. Kellerman said about the Massachusetts results being different from others, in the time taken for sedimentation of copper, etc. I think we really ought to have a standard method for the determination of copper in water. I have not seen in the published reports of the amount of copper found in the various western reservoirs after treatment any statement as to the way the copper present was determined. The general method of determining copper is by the potassium ferro-cyanide test, which is only delicate enough to show a part

of copper in about two million parts of water, — that is, distilled water. If you have a natural water which is colored with iron and organic matter, the color given by the test is very much disguised, even when copper is present in the amount just stated. The method we have evolved at the laboratories of the State Board of Health in Boston, and which has been adopted by the Committee on Standard Methods of Water Analysis of the American Public Health Association, is quite different from that. It is a long and rather tedious method, perhaps, but we can determine copper accurately when it is present in water in very minute amounts. It is simply a question of patience and having water enough and evaporating it down, getting rid of the iron and organic matter and silicates present, and then depositing the copper by electrolysis on platinum dishes. It is easy to work and accurate. I think if that method was more generally in vogue we should know more about the sedimentation of copper in some of these western reservoirs which have been treated. In saying that I do not mean to cast any reflection on the ability of the various chemists who have tested the water in those reservoirs, but I imagine they haven't used a delicate enough method for determining copper.

Prof. Herbert E. Smith. I have already used my quota of time, but I will take a moment, if I may, to refer briefly to a couple of cases which have come within my observation. These are a little interesting, because they were cases of a considerable growth of *Uroglena* in reservoirs which are not commonly affected by other troublesome growths. They both occurred during the early part of the present year, in Connecticut, and the treatment of them with copper sulphate was successful, at least it was followed by a happy result as far as the removal of the organism was concerned, and in that it was not followed by the development of any other organism.

One of the reservoirs was treated with copper sulphate to the extent of one part in nine millions. That reservoir was not in use at the time. The other reservoir was a larger one and was in use and was treated with copper sulphate to the extent of one part in about sixteen millions. This particular reservoir had

about forty colonies of *Uroglena* per cubic centimeter at the time of the treatment, and the odor of the water was exceedingly offensive in the town where it was used. The odor rapidly disappeared, so that at the end of four days there was no complaint of the water in the town, and there were none of the organisms to be found in a half liter of the reservoir water.

Mr. D. D. Jackson. The first experiments of the writer on the treatment of water with copper sulphate were made upon Baiseley's Pond, Jamaica, L. I., on September 6, 1904. As all of the water used from it is subsequently filtered, it was considered that there could be no possibility of the presence of copper sulphate after filtration, as this chemical does not remain in solution in the water, but is immediately precipitated by the carbonates present. At the time of treatment the pond contained a considerable growth of anabæna. On account of its gelatinous nature this organism was giving great trouble in the mechanical filters and had at times caused a reduction of as high as 25 per cent. in the rate of filtration. Table 1 gives the results obtained.

Table 1. — Reduction of Algæ in Baiseley's Pond Due to Copper Sulphate Treatment.

Date, 1904.	Location.		Total Organisms.	Anabæna.
Sept. 6,	Top	Before treatment	1 640	800
„ 6,	Bottom	„ „	435	265
„ 7,	Top	After „	155	55
„ 7,	Bottom	„ „	235	0
„ 8,	Top	„ „	105	0
„ 8,	Bottom	„ „	150	0
„ 9,	Top	„ „	125	0
„ 9,	Bottom	„ „	125	0
„ 10,	Top	„ „	175	0
„ 10,	Bottom	„ „	105	0
„ 30,	Top	„ „	140	0
„ 30,	Bottom	„ „	100	0

The amount of copper sulphate used was approximately 1 part in 8 000 000 parts of water, and the expense of treatment for 100 000 000 gallons was $7.50.

On the third day after treatment the wash water of the filter was reduced to 3 per cent., causing a saving in the yield of the plant for that time of 1 000 000 gallons per day.

Copper sulphate experiments were next made on an extremely heavy growth of clathrocytis, an organism closely related to anabæna, and one which is often found in large quantities in surface waters. This microscopic growth occurred in the Prospect Park Duck Pond near Flatbush Avenue, Brooklyn, in such enormous amounts as to entirely cover the surface of the pond with a thick green slime. Table 2 gives the results obtained by the treatment of this organism.

TABLE 2. — REDUCTION OF ALGÆ IN PROSPECT PARK DUCK POND DUE TO COPPER SULPHATE TREATMENT.

Date.	Location.		Units of Clathrocytis.
Sept. 9,	Top	Before treatment	700 000
„ 9,	Bottom	„ „	10 000
„ 10,	Top	After „	620 000
„ 10,	Bottom	„ „	83 000
„ 11,	Top	„ „	94 000
„ 11,	Bottom	„ „	35 000
„ 12,	Top	„ „	7 625
„ 12,	Bottom	„ „	2 550
„ 13,	Top	„ „	560
„ 13,	Bottom	„ „	640

The amount of chemical used was approximately 1 part in 4 000 000, and the cost of treating the pond was $2. During the present summer this treatment has been extensively used in the Brooklyn Department of Parks and has been found effectually to remove the disagreeable odor and unsightly appearance occurring so often in the park ponds, and in the dilutions used there has not been the slightest injury to shrubbery or fish.

During the month of September, 1904, a considerable growth of an alga known as aphanizomenon occurred in one of the sources of water supply for the borough of Manhattan, and its presence was the cause of a considerable taste and odor in the water.

On September 30, the surface of this reservoir was treated with copper sulphate in the proportion of 1 part to 8 000 000 parts of water. This amount of copper sulphate, providing it all remained in the water, would necessitate an individual to drink 100 gallons of water a day to get the slightest physiological effect from the copper, and there is, therefore, no question about the safety of such a treatment as this, especially as only one or two treatments a year are necessary. Table 3 gives the results obtained.

TABLE 3. — REDUCTION OF ALGÆ DUE TO COPPER SULPHATE TREATMENT, BOROUGH OF MANHATTAN WATER SUPPLY.

Date.	Location.		Total Organisms.	Aphanizomenon.
Sept. 30,	Top	Before treatment	4 680	4 100
„ 30,	Bottom	„ „	4 115	3 725
Oct. 1,	Top	After „	1 020	755
„ 1,	Bottom	„ „	565	285
„ 2,	Top	„ „	490	240
„ 3,	Top	„ „	140	0
„ 3,	Bottom	„ „	275	0

The figures of the above table show that this form of blue-green algæ was completely removed on the third day after treatment. From that time on the water has been clear and free from unpleasant odors.

Later in the year the microscopic organism uroglena occurred in large numbers in one of the Brooklyn supply ponds. This organism produced a strong fishy taste and odor in the water, and considerable numbers were being transported to the Ridgewood and Mt. Prospect distributing reservoirs. In order to prevent any further influx into the reservoirs of this odor-producing organism, the pond was shut off and a treatment with copper sulphate was made on November 23, 1904. As this is an extremely delicate organism a dilution was used of only 1 part of copper sulphate to 20 000 000 parts of water. Table 4 gives the remarkable results obtained.

TABLE 4. — REDUCTION OF UROGLENA DUE TO COPPER SULPHATE TREATMENT, BROOKLYN WATER SUPPLY POND.

Date.		Uroglena (Units per cc.)
Nov. 23,	Before treatment	1 100
Nov. 25,	Two days after treatment	450
Nov. 27,	Four days after treatment	0

During the present year no trouble has been experienced from microscopic growths in this pond.

In the spring of the present year one of the Brooklyn sources of supply was treated with copper in order to remove a growth of asterionella. It was found that 1 part of copper sulphate in 3 000 000 parts of water was necessary. Table 5 shows the results obtained.

TABLE 5. — REDUCTION OF ASTERIONELLA DUE TO COPPER SULPHATE TREATMENT, BROOKLYN WATER SUPPLY.

Date.		Asterionella.
May 2,	Before treatment	2 850
„ 3,	„ „	3 400
„ 4,	„ „	3 650
„ 5,	After „	2 450
„ 6,	„ „	2 350
„ 7,	„ „	2 200
„ 8,	„ „	1 275
„ 9,	„ „	875
„ 10,	„ „	640
„ 11,	„ „	550
„ 12,	„ „	380
„ 13,	„ „	310
„ 14,	„ „	260
„ 15,	„ „	200
„ 22,	„ „	25

It will be seen from the above figures that not only does asterionella require more copper for its removal, but the reduction in the organisms appears to take place much more slowly.

Amount of Copper Necessary for Treatment. — The amount of copper required to remove a growth of micro-organisms from water depends to a large extent upon the structure of the particular organisms present. A definite amount of copper is required each time the treatment of any particular genus is made, excepting when the growth is extremely heavy, when it may be even necessary to double the quantity. In general the amounts of copper so far found to be required are as follows:

(PARTS OF WATER TO ONE OF COPPER SULPHATE.)

DIATOMACEÆ.			
Asterionella	3 000 000	Synedra	1 000 000
Melosira	3 000 000	Fragilaria	4 000 000
CYANOPHYCEÆ.			
Coelosphaerium	4 000 000	Anabæna	8 000 000
Oscillaria	5 000 000	Aphanizomenon	8 000 000
Microcystis	6 000 000	Clathrocystis	8 000 000
CHLOROPHYCEÆ.			
Draparnaldia	3 000 000	Closterium	3 000 000
Scenedesmus	3 000 000	Volvox	4 000 000
Conferva	3 000 000	Spirogyra	5 000 000
Raphidium	3 000 000	Hydrodictyon	10 000 000

PROTOZOA.

Chlamydomonas	2 000 000	Mallomonas	2 000 000
Cryptomonas	2 000 000	Dinobryon	3 000 000
Euglena	2 000 000	Synura	10 000 000
Glenodinium	2 000 000	Uroglena	20 000 000
Peridinium.....	2 000 000		

It will be seen from the results that if the nature of the growth is not known a treatment of 1 part in 2 000 000 parts of water will be in all probability sufficient to accomplish the work. If, however, the organism is known, a much smaller amount may, in most cases, be used.

Recurrence of Growth. — It sometimes happens that a short time after a pond has been treated, and the growth removed, a second growth will develop. This second growth may be the same organism as the first, or it may be an entirely different organism. The fact that a second or third growth sometimes develops is in no way remarkable when we consider that the copper added is usually precipitated to the bottom in a few days and becomes inactive in the water above. If the conditions are favorable for a second development there is nothing but the reduction of spores to prevent its occurrence, but it has been noted that it is only in ponds or reservoirs highly contaminated with organic matter, and having large deposits of muck at the bottom, that such repeated growths do occur. In such cases, if the ponds are not cleaned, it may be necessary to treat them four or five times during the year. It has been claimed that a pond once treated with copper sulphate will require a stronger treatment for the second growth. This has not been the experience of the writer.

Influence of Copper on Bacteria in Water. — When a heavy growth of algæ is destroyed by treatment with copper, the dead organisms furnish food for the development of bacteria, and unless the algæ are rapidly precipitated to the bottom of the pond, then with the fall in algæ comes a marked rise in bacteria. Water bacteria require very strong solutions of copper to produce the slightest effect upon them. Table 6 shows the effectu pon the common water bacteria produced by the treatment of copper (1 part in 3 000 000 parts of water) in a reservoir containing asterionella.

TABLE 6.—EFFECT OF COPPER SULPHATE ON COMMON WATER BACTERIA AFTER REDUCTION IN ASTERIONELLA.

1905.			Microscopic Organisms.	Bacteria.
March 13,	Before treatment		4 625	405
„ 14,	After	„	3 645	600
„ 15,	„	„	3 325	6 000
„ 16,	„	„	1 925	11 000
„ 17,	„	„	1 850	12 000
„ 18,	„	„	1 575	45 000
„ 20,	„	„	1 350	100 000
„ 21,	„	„	900	440 000
„ 22,	„	„	350	630 000
„ 23,	„	„	350	310 000
„ 24,	„	„	400	107 000
„ 25,	„	„	360	80 000
„ 26,	„	„	300	64 000
„ 27,	„	„	270	50 000
„ 28,	„	„	150	37 000
„ 29,	„	„	100	20 000
„ 30,	„	„	100	8 000
„ 31,	„	„	60	3 500
April 1.	„	„	25	860

PROF. W. P. MASON. Since listening to this very interesting discussion I cannot say that I am particularly enthusiastic about the use of copper sulphate for the removal of the typhoid bacillus from a drinking-water supply. There seems to be quite a bit of difference of opinion here. I noted in particular how much advantage was claimed from the accumulation of copper salts in the upper reaches of the sand bed. It seems to me that if we are obliged to use a filter anyhow, it scarcely would be wise to go to the expense of the introduction of copper sulphate before such use. The efficiency of the sand bed or of the mechanical plant, or of any good form of modern filter, is already high, and I do not believe that such efficiency is going to be materially increased by adding copper sulphate to the water before it is filtered. There is no question whatever that there is a very violent popular prejudice against such an addition.

DR. EDWIN L. NEWCOMB.* It seems to me the use of copper sulphate is not intended to replace the filtration beds, but it is

* Philadelphia College of Pharmacy.

simply intended to be used as an adjunct where we have insufficient filtration, or filter beds which are not deep enough to filter sewage or applied water so as to render the effluent suitable. The only point remaining is whether copper will kill typhoid and other organisms which pollute the sewage, or which render the water sewage, and if it is possible to kill them, then it seems to me it is a very valuable adjunct to the filter beds which do not sufficiently filter the water.

DR. GEORGE T. MOORE. I really do not think there is anything left for me to say. We have had a very full and interesting discussion, and a number of points have been referred to which I think all of us wish to clear up if possible. The discrepancy in the experience of the various ones who have reported requires some explanation, and I am sure that further opportunity for experiments along all lines will clear up matters which now seem doubtful.

It should be borne in mind that so far as the original projectors of the copper method of purifying water are concerned, it was not contemplated in any way to replace efficient means already in existence. Aside from the destruction of algæ, it was simply intended to suggest a possible emergency method for handling typhoid where a sand filter did not exist, and no other means for purifying the water were available. And under such conditions I still believe that the authorities would be justified in temporarily resorting to copper sulphate for purifying the water supply. The suggestion of the use of copper in destroying typhoid germs did not contemplate a continuous treatment, but rather the rapid sterilization, if I may use that term, of water which had been subjected to accidental pollution; a condition which would not occur again because of precautions immediately taken.

The other aspect of the question, the use of the method in connection with filters, is something with which we have had but little experience, and requires further experiments. Our intention and desire has been to put before the public all the information which could be obtained, and allow those who are competent to draw their own conclusions.

The same is true regarding the effect of copper upon man.

The very thorough and interesting discussion by Dr. Smith probably had one effect on those who consider copper a poison, and another on those who do not think it so. Any experience I have had with boards of health throughout the country would seem to indicate that mere evidence produced on either side of the copper question had little or no effect on the medical men present. It is, of course, practically impossible to introduce the use of copper sulphate into any community for any purpose whatever, where there is opposition of the medical authorities, whether state or local boards of health. And thus the thing really resolves itself into a local question. There is little use discussing the question or trying to prove that copper is or is not a poison, if you have the local board of health against you. They are usually not open to argument of the character which has been presented here. For this reason it is not probable that there will be any general adoption of a method of this kind, for, as Professor Mason says, there is undoubtedly a strong popular prejudice against the use of copper. This point, however, does not need discussion here, being one which must be considered entirely in the light of local conditions.

The point that Mr. Clark referred to, the standardizing of a test for copper, seems to me most important. We have had and will probably continue to have conflicting results regarding the presence of copper, or the amount of copper remaining in a water after treatment. Some of this may be due to the difference in the character of the water; probably a certain amount of it is due to the difference in the way in which the copper is determined. Any method which will result in getting comparable results, or standardizing the whole process, is much to be desired; and I hope that in the future, when comparisons of this kind are made, we may be sure that the methods used were the best and that they have been carried out most carefully. The only difficulty that I can see regarding the method that Mr. Clark uses is the fact that it is so complicated and requires the addition of so many different substances — distilled water, various acids, etc., — which, of course, must themselves be tested for copper. In incompetent hands, outside of well-equipped laboratories, the chances for mistakes and the finding of large quantities of

copper where little or none occurs in the water, by such a method, are greatly increased. For this reason I wish we might have a simpler method which could be used universally and thus eliminate as much as possible the opportunity for error.

Dr. Frederick S. Hollis * (*by letter*). In the various papers presented that have treated so fully all sides of the copper sulphate method, we are fortunate in having records from different sections of the country, representing the action of copper sulphate on organisms growing in waters having markedly different characters, especially in regard to hardness and alkalinity, and probably, too, in the amount of organic matter in solution such as gives the color to our northern waters.

Water like that reported from Ohio, having hardness as high as 400 and alkalinity 100, will naturally precipitate the copper more promptly and completely than a Massachusetts or Connecticut water having hardness and alkalinity of from 10 to 20, and it is probable, too, that certain organic matter held in solution in the water, as well as carbonic acid, may have considerable to do in retarding precipitation. Those of us who have made applications of the method have generally been asked how long the sulphate added will act to keep down the growths and whether the successful removal of a growth one season will prevent it from occurring the following year. Neither of these questions can be answered definitely, but, from what has already been brought out, I feel that I have been quite safe in stating that in most waters probably enough will not remain in an active form to act very long after the time of treatment. The complete or nearly complete removal of a form of growth ought, through the prevention of the formation of spores from which the growth in the following season starts, to greatly lessen the chances for a repetition of the growth. On visiting the reservoirs from which a growth of Anabæna was removed last summer at the time when the growth last year was at its height, only a negligible amount of Anabæna was found and the water had up to that time given no trouble from any growth.

That judgment is necessary in making the application so as

* Yale Medical School, New Haven, Conn.

to avoid the loss of sulphate due to settling from the line of strong solution following the boat, in case there is not sufficient wind to effect rapid and complete mixing, has already been mentioned. In the applications that I have made, I have calculated that the sulphate added necessary to give for the entire contents of the reservoir an amount equal to 1 part in 5 000 000 or .2 part per 1 000 000, really went into solution in a line having a strength of 1 part in 250 or 4 000 parts per 1 000 000. These applications were all made when there was considerable wind and in comparatively shallow reservoirs, where the wind influences easily reached to all depths.

While making the applications unsparingly over the shallow flowage and areas covered with water weeds, which I determined to be the breeding places of some of the forms that it was desired to remove, it has not been my misfortune to kill any fish, although the reservoirs were well stocked with bass, pickerel, perch, and eels. Bacteria I have found to increase, in one case twentyfold, after an application of .2 part per 1 000 000, which is readily accounted for by the increase of food material supplied by the bodies of the forms that have been killed. All of the accounts show the absolute necessity of the careful determination of the microscopic forms present before making the application because of the great difference in susceptibility of different forms.

The results show clearly that two of the most objectionable forms, Anabæna and Uroglena, yield to amounts so small that there ought to be no prejudice against its use, and that the value of the method cannot be overestimated even if only for the restriction of these two forms.

Growths of many forms are retarded or held in check by an amount of sulphate inadequate to exterminate them, while in my experience a growth of Chlamydomonas increased following the treatment for the removal of Anabæna, imparting its sharp odor and taste to an extent sufficient to offset largely the value derived from the complete removal of Anabæna. Fortunately growths of Chlamydomonas are uncommon and such a case would rarely be met with. While in writing an account of my tests I used the method that has commonly been employed in recording the amount of copper sulphate, I, with others, would

favor reporting it in parts or decimals of a part per million, uniform with the method of reporting chemical analysis.

Copper Sulphate as an Adjunct to Sewage Disposal.

BY EDWIN L. NEWCOMB, PHARM. D. [*By letter.*]

One of the most useful purposes which copper sulphate promises to serve in the purification of waters is in the treatment of sewage.

Before giving the results of the experiments which I have carried out along these lines, I wish first to state the conditions with which I have had to deal.

The disposal field upon which I have been experimenting is located at Vineland, N. J., and consists of eight filter beds and three settling beds, or septic tanks, which are used at present for separating out the larger portions of solid matter and obtaining a septic action. The filter beds are from 150 × 150 feet to 150 × 200 feet in dimensions, and the amount of sewage to be cared for daily is approximately 280 000 gallons. The filtering material in the filter beds consists of coarse cinders around the drain tiles, gradually decreasing in coarseness until the natural soil is reached, which consists mostly of fine sand and some gravel. This layer of filtering material varies from two feet in thickness at the upper side of the field to about four feet at the lower side; through this thin layer of filtering material an exceedingly rich sewage must pass, and a filtrate suitable to enter a drinking-water supply be obtained.

Experience has taught that it is almost impossible to filter a rich sewage through such a thin filter as this and obtain a filtrate which is fit to enter a drinking-water supply.

The surrounding physical conditions being such that it was impossible to increase the depth of the filters, and as the filtrate was badly contaminated with intestinal organisms, I decided, after consulting Dr. Moore and Mr. Kellerman, of Washington, D. C., to try copper sulphate.

In connection with Mr. Kellerman, I went over the system, and together we laid out a plan of procedure; an examination was made of the raw sewage, both chemically and bacteriologically; the only apparently interfering substance from a chemical point of

view was the organic matter, which was largely albuminoid in form, and hence would have a great tendency to precipitate out the copper salts.

Space will not permit me to give in detail the results of all the experiments carried out; a brief summary will be all that is possible here.

Copper sulphate was first applied to the raw sewage in a quantity such that it made a solution, approximately, 1 part of copper sulphate to 100 000 parts of sewage. The copper was added in concentrated solution by means of an automatic feed. The first noticeable results were that the gate chambers and connecting pipes between the beds attained a much more sanitary condition, so that there was almost no odor due to algæ, with which they were previously infested. It was also noticeable that a large quantity of copper had been precipitated out by organic material and floated about the surface of the filter bed; this was probably an albuminate of copper possessing less germicidal properties than the sulphate.

The bacteriological examination of the filtrate showed that there was a gradual decrease in the number of intestinal organisms, and at the end of eight days no coli developed on litmus lactose agar, and there was also a very noticeable decrease in the total number of organisms. The results of these tests were satisfactory in a measure, but not altogether, for some counts showed that there seemed to be a deficiency of copper, due, no doubt, to the fact that at times more was precipitated out by the organic matter.

I therefore began using the settling beds as septic tanks and adding copper sulphate to the clarified sewage as it came from these tanks. By this manner of operation the larger portion of organic matter is broken up by the action of the nitrifying organisms in the septic tanks; therefore, only a small quantity of copper is lost by precipitation. It has been proven that where bacillus coli and other intestinal organisms were found in the filtrate from the beds when no copper was used, there were absolutely no intestinal organisms to be found after the use of copper sulphate; thereby rendering the effluent free from pollution and fit to enter a drinking-water supply.

The determination of sewage can no longer be made upon a chemical analysis alone, for as Dr. Henry Kraemer of Philadelphia stated, "Although previous authority based the determination of sewage on the amount of nitrites, chlorine, ammonia, etc., this can no longer be taken as a criterion, as a water supply may contain any or all of these substances, and at the same time not have a single trace of sewage present." "Sewage, according to the modern translation of the word, is any water which contains coli organisms."*

The determination of the exact amount of copper sulphate necessary to render water free from coli is as yet a problem, the two chief factors which determine the amount necessary in this case being temperature and the amount of organic material. At one time I was using but one part of copper sulphate to 175 000 parts of sewage, but a change in temperature caused me to return to 1 part to 100 000 of sewage.

Tests have been made repeatedly for copper in the filtrate by the delicate potassium ferro-cyanide test, and the water at all times has given no discoloration.

In conclusion, it has shown that where filtration plants fail to do satisfactory work, due to the non-elimination of intestinal organisms, copper sulphate is a practical means by which the filtrate may be rendered free from disease organisms, and as has been stated by Dr. Kraemer, "It has the added advantage of completely destroying the organisms, as well as removing them." †

Notes on the Use of Copper in China.

BY S. P. BARCHET, M.D.‡ [*By letter.*]

Copper and brass cash are the standard coin of China, handled daily by old and young. Copper also figures largely in the make-up of kitchen utensils; copper ladles, copper kettles, and copper pots being in general use.

* "Third Report on Experimental Work on Sewer Beds, Vineland, N. J.," by Edwin L. Newcomb.

† Amer. Med., Vol. ix, No. 7.

‡ Annapolis, Md.

It is no uncommon sight in Mid-China to see rice boiling in copper pots with verdigris around the rim, yet the people who eat the rice are hale and hearty.

Foreigners who, to my knowledge, have partaken of food prepared in copper vessels, did not suffer in any way.

In my medical practice, extending over twenty odd years in the Province of Chegiang, I met with not a few cases of poisoning by opium; also with a few cases of poisoning by salts of mercury, or arsenic; but I never saw there a case of poisoning by copper.

Children who had swallowed cash were occasionally brought to the hospital, but apart from mechanical obstruction, no untoward symptoms developed in those cases. Nor have I seen a case of copper poisoning recorded in any of the medical reports of mission hospitals in China.

It may be that the long-continued use of copper has made the Chinese not so susceptible to the irritant action of copper salts, or that the minute quantities swallowed are insufficient to produce characteristic symptoms.

From extensive applications of the sulphate of copper in certain troubles of the eye, I have only seen beneficent results.

The remarkable power of copper and its salts as an algicide and germicide, as demonstrated by Drs. Moore and Kellerman, throws some light on the comparatively good health of crowded and insanitary Chinese cities, whose inhabitants drink mainly hot water, tea, or wine, boiled in copper vessels.

Mr. G. C. Whipple (*by letter, November 27, 1905*). During the last few days I have had an opportunity of looking over a report made to the Brisbane, Australia, Board of Water Works by Mr. Hardolph Wasteneys, analyst of the board.

The report is dated May 15, 1905, and relates to an experimental investigation of the effect of copper sulphate on algæ. The results of Mr. Wasteneys' experiments do not differ greatly from those which have been obtained in the United States. The organisms which he has had to contend with, however, are somewhat different from those which are common in these regions. In particular he mentions a form called Microhaloa, which is said to be similar to Palmella hyalina, although somewhat larger. The most common

organisms present in the water at the time when he made his experiments were Microhaloa, Anabæna, Spirogyra, and Peridinium. These organisms were practically all killed in forty-eight hours with one part of copper to four million parts of water. The Microhaloa and Anabæna succumbed with one part of copper to eight million parts of water.

Mr. Wasteneys' report gives his results in full detail, using the standard methods so well known in this country.

He also experimented with large sheets of copper suspended in running water, but found that, although it retarded somewhat the growth of the zygnema which was present in the water, it by no means killed it, and his conclusion was that the use of sheet copper as an algicide would not be successful in practical applications to their water supply.

Some of his descriptions of the occurrence of algæ in the reservoirs of the Brisbane Water Works are of much interest, and we may hope to have, at some time in the future, a paper by Mr. Wasteneys describing the work which he is doing in Brisbane.

Mr. C. Arthur Brown * (*by letter*). I have listened to the papers read with much interest and some perplexity. It seems strange that such wide differences of opinion as to the removal of copper and its salts from water should exist among the workers who have taken part in this discussion. Evidently something is wrong. Even admitting that there is a certain amount of prejudice among those experimenting along this line, the expressions are at too great variance to be explained on this basis. I think one or two of the speakers have touched on what is probably the real trouble. It is, I think, necessary to know more about the type of water which is to be treated and to understand more thoroughly the reactions which will occur when copper or its salts are added to such a water.

My belief is that the work must be brought to a more scientific basis, and the men using these materials must do their work along better defined lines and with less guessing at what is going to be the result. It seems to me we have not found as yet the underlying principle on which good work must be done and

* Lorain, Ohio.

satisfactory results secured. Possibly I may be able to add my mite to the sum total of knowledge on this subject.

Ignoring, if I may, the question as to whether copper is or is not injurious to water users, if present in small amounts in potable waters, I wish to give briefly my experience and to state in a general way the results obtained by its use. In my early work on the use of copper sulphate, I found it necessary to know positively the character of the water to be treated, and likewise, the character of the water after treatment. I soon found that if the water to be treated contained as much half-bound carbonic acid as it did combined carbonic acid, the tendency was to hold copper in solution for a greater or lesser period of time. If a large amount of organic matter was present, this tendency was stronger, and if, in addition, some free carbonic acid was present, the tendency was still stronger. This led me to attempt to secure the removal of the copper by establishing different conditions. I soon found that if the free carbonic acid and a small portion of the half bound could be absorbed by caustic lime, then copper sulphate could be added with impunity, in reasonable quantity, and the consequent removal, either by sufficient sedimentation or filtration, was as perfect as could be desired. I also found that the precipitated copper was as efficacious, apparently, as a germicide as was necessary, and if it was allowed to accumulate on a filter bed, manifested no tendency to go into solution again.

These theories were given a practical test at Anderson, Ind., in the filter plant installed by the city, which was then furnishing water to supply the demands of Anderson. A summary of this test has been reported by Dr. Moore and Mr. Kellerman in their last "Bulletin" on this subject. The removal of the copper seemed to be complete, 10 liters of the filtered water being used for the purpose of testing for the presence of copper. Some criticism was offered on the quantity used for testing, the critics claiming that the amount taken was not large enough. Another test of the process was made at a later date at Marietta, Ohio. This test was also on a large scale. In taking the samples to be tested for copper at this point, I tried to use as large a quantity of the filtered water as was practical, taking a 200-gallon sample and evaporating to dryness. Later on, Professor Monfort took

100 gallons for the same purpose. The fact that copper is found in so many substances led me to think that it might possibly be found in natural water if large enough quantities of the same could be examined. At the time the filtered sample was taken, I therefore took 200 gallons of the river water and subjected it to test. The 200 gallons of river water yielded 0.10015 grams of metallic copper, while the 200 gallons of filtered water contained 0.00275 grams of metallic copper. It was afterwards ascertained that the latter amount was too large in all probability, as care had not been taken to collect the sample before passing the pumps and other brass fittings; but even assuming the amount present in the filtered water to be correct, there is shown to be present only 1 part of copper in 275 286 000 parts of water, while the river water in its normal condition at that time carried thirty-six times as much copper. Yet people have drunk this water as far back as our knowledge goes, and we have no record of copper having any injurious effects upon them.

Later determinations by Professor Monfort and myself of the amount of copper in the river and filtered waters, the filtered water being taken under additional precautions to prevent recontamination by copper, confirmed the results above given, with the exception that the quantity found in the filtered water was proven to be much smaller. These results were checked often enough to make us certain of our position.

In this case, we find that 97 per cent. of the copper present in the river water is removed by this process, and in addition, *all* the copper used in filtering is taken out as well. The reason is easily seen. Copper sulphate is practically insoluble in a water containing normal carbonates. By absorbing a small portion of the half-bound carbonic acid, we brought about the presence of normal carbonates in the water to which the copper salt was added. The water entering the settling basins of the filter plant, after the lime, iron, and copper had been added, gave a distinct reaction to phenolphthalein.

It is my belief that some of the results obtained by the others who have spoken on this subject were not such as would have been secured had they established the conditions above spoken of. If enough caustic lime is added to absorb all of the free and a

portion of the half-bound carbonic acid, you can then apply salts of copper and secure practically complete elimination. This does not interfere in any way with the germicidal action of the copper salt as far as I have been able to ascertain. A complete report of the work done at Marietta will appear within a very short time. I shall not say a great deal about the bacterial results obtained, but I should like to mention the fact that no sample of the filtered water contained *B. coli communis*.

MR. GEO. T. PRINCE.* A small lake located in one of the parks of Denver has given reason for complaint during past seasons because of the offensive odor that arises as a result of the presence of micro-organisms in the water. It was determined to try the effects of copper sulphate not only as a remedy to this trouble but also to gain some knowledge from experience in determining whether we would resort to copper sulphate in any of our reservoirs should occasion require.

The lake was treated on August 10, last, the temperature of the water at the time of treatment being 24.5° C. The capacity was estimated at 4 000 000 gallons and the lake covers approximately one acre of ground. Sixteen pounds of copper sulphate of a solution of one part in two million parts of water were applied. All samples were taken at a certain point throughout the experiment. The sample taken just before treatment contained a vast amount of microscopic organisms. Most of these organisms can be grouped under the head of cyanophyceæ, or blue-green algæ. They consist of ananbæa circinnalis, anabæna flos aquæ, aphanizomenon and clathrocystis and the number of standard units of each was noted.

The bacteriological analysis before treatment showed 6 200 bacteria per cubic centimeter. The sample also contained *bacillus coli*.

A blue-green surface scum was scattered over the greater portion of the lake.

The copper was applied by placing it in two gunny sacks which were suspended over the stern of a boat that was rowed over the surface of the lake. It took about two hours to complete the treatment.

* Chief Engineer, Denver Union Water Company, Denver, Colo.

About twelve hours after treatment a sample of the water was taken and no trace of anabæna could be found. Aphanizomenon had almost disappeared and about 25 per cent. of the clathrocystis. Twenty-four hours after treatment a thick scum had collected in one arm of the lake near the inlet. A blue-green scum was also visible around the edges on the shore. The sample taken at this time showed an entire absence of anabæna and aphanizomenon and a reduction of over sixty per cent. of clathrocystis. Very little effect on the crustaceæ was noticeable, except they were more sluggish in their movements. The number of bacteria was 135 000, multiplication evidently being due to the increased supply of food furnished by the dead algæ. Tests for coli were negative.

Forty-eight hours after treatment the water was quite turbid and the surface scum remaining was scattered throughout the lake. The clathrocystis was apparently dead and only twenty per cent. of the original amount was present. The diatom navicula showed no signs of life at this time. A few dead crustaceæ were found also. About the same number of bacteria were found, the count being 130 000 per cubic centimeter.

On the third day the water looked much clearer and the surface scum was practically all gone.

On the fourth day another sample was taken and no algæ were to be found. The bacteria had decreased to 82 000. The water was much clearer and no scum was visible.

It was not deemed necessary to prolong the investigations further.

Tests were made for copper sulphate in 1 000 cubic centimeters of the sample taken on the fourth day and the reaction was negative. The delicate posassium ferrocyanide test was used. By this test it is possible to detect 1 part of copper in 2 500 000 parts of water.

In the latter part of September one of our reservoirs was so badly affected by the presence of anabæna that we decided to resort to copper sulphate as a remedy. The reservoir at this time covered 600 acres of ground and contained approximately 4 500 000 000 gallons of water. We began to apply the sulphate at 2.30 P.M., October 6, and the work was continued during that day,

the following day, and half of the next day. We used in all 10 000 pounds of copper sulphate. The sulphate was placed in gunny sacks, each of the sacks containing about seventy-five pounds. A gasoline launch was used in the process of applying the sulphate, three bags being suspended on each side of the launch from outriggers.

Analyses were made, both biological and bacteriological, of the samples of water taken before treatment and every twenty-four hours after treatment for five days, also the delicate potassium ferrocyanide test was used in determining the presence of copper in the water but with negative results, showing that the copper had been entirely absorbed by the micro-organisms in the water.

The application of copper sulphate had an immediate effect upon the microscopic life contained in the water and also upon the odor. It will be noticed that anabæna disappeared entirely within twenty-four hours after treatment and that the more persistent organisms gradually succumbed to the influence of the copper until, nine days after treatment, the analysis shows the water to be practically free from these micro-organisms with the exception of bacteria, which, as will be observed, multiplied very rapidly after the copper sulphate had been applied to the water, due undoubtedly to the presence of dead algæ.

The color of the lake water was changed in consequence of the treatment and resembled more a body of salt water than fresh in appearance.

The results were very satisfactory and the condition of the water in the lake made it possible to place the lake in service.

The bacteriological count has decreased rapidly and on October 25 there were present 4 750 colonies per cubic centimeter.

NEW ENGLA

TABLE SHOWING EXPERIENCE IN THE

(Compiled from

Place	Body of Water Treated			Organisms Causing Trouble	Date	Ratio, Million Parts of Water to one of Copper Sulphate	Treat	
	Name	Cap. Million Gallons	Area — Acres				On Organisms	
New Hampshire								
Hanover	Reservoir	150.0	36.0	Uroglena Anabæna	July, 1904	4.0	Destroyed in 3 days	
				Uroglena Anabæna	May, 1905	4.0	Destroyed in 5 days	
Massachusetts								
Arlington	Reservoir	65.9	29.2	Scenedesmus	August 5, 1903	1.8	None	
				Anabæna Aphanizomenon Staurastrum	July 28, 1904	3.7	Anabæna Aphanizomenon } destroyed Staurastrum, none	
Belchertown	Reservoir	55.7	35.0	Chara Anabæna	July 21, 1904	8.0	Anabæna destroyed Chara, none	
		35.0 when treated		Chara Anabæna	June 13, 1905	8.0	Anabæna nearly destroyed Chara, none	
Newton	Crystal Lake	143.0	31.0	Anabæna	August 18, 1905	4.0	Destroyed	
Jamaica Plain	Jamaica Pond	600.0	69.0	Oscillaria	September 22, 1903	4.2	Fell off slightly	
				Oscillaria	August 19, 1905	1.8	Disappeared in 6 weeks	
Lexington	Reservoir	8.0	6.2	Uroglena	June 30, 1905	20.0	Destroyed	
Sharon	Massapoag Lake	1148.0	352.0	Anabæna	November, 1904	5.0	Destroyed	
Connecticut								
Greenwich	Rockwood Reservoir	325.0 (235.0 when treated)	93.0	Conferva Spirogyra Anabæna Chlamydomonas	July 26, 1904	5.6	Anabæna destroyed, others greatly reduced	
	Putnam Reservoir	300.0 (150.0 when treated)	100.0	Tabellaria Anabæna	July 30, 1904	5.0	Anabæna destroyed, others greatly reduced	
New York								
Amsterdam	Reservoir	100.0	13.8	Anabæna	July 1, 1905	8.3	Destroyed in 5 days	
Clinton	College Reservoir	0.5		Chara	July 1, 1905	1.0	Checked growth	
Elmira	Impounding Reservoir	113.0 (90when treated)	38.0	Asterionella Anabæna	June, 1903	1.0 (about)	Destroyed in 3 days	
Hartwood	Hemlock Lake	111.0	57.5	Anabæna	July 11, 1905	8.3	Destroyed	
Middletown	Shawangunk Reservoir	316.8	87.7	Oscillaria Anabæna	June 23, 1905	1.9	Destroyed	
	Highland Reservoir	451.6	110.0	Protococcus Oscillaria	July 15, 1905	2.9	Destroyed	
	Monhegan Reservoir	255.1	74.0	Anabæna	July 20, 1905	3.2	Destroyed in 7 days	
Waldheim Scarboro' on Hudson		40.0		Hydrodictyon	June 16, 1904	5.5	Destroyed in 3 days	
Water Mill	Pond	11.5		Cladophora Entomophora	June, 1904	2.0	Destroyed in 7 days	
				Cladophora Entomophora	July 1, 1905	2.0	Destroyed	
New Jersey								
Atlantic City	Basin	0.6	0.6	Ulothrix	May 17, 1905	See Remarks	Destroyed	
Pennsylvania								
Millersburg	Reservoir	0.5		Fragilaria	May 1, 1905	0.8	Destroyed	
Williamsport	Upper Reservoir	21.9	7.0	Clicha algæ	May 15 and 26, 1905	1.3	Destroyed	
	Lower Reservoir	6.0	4.0	Clicha algæ	May 26, 1905	1.5	Destroyed	
Maryland								
Port Deposit	Reservoir	10.0	2.5	Chlamydomonas	May 6, 1904	1.0	Destroyed	
South Carolina								
Charleston	Reservoir	a 134.2	2000.0	Crenothrix Anabæna Oscillaria	About 1 month was occupied in dissolving the copper sulphate	1.3	Destroyed	
Greenwood	Reservoir	0.5	0.2	Conferva	June 15, 1905	1.0	Destroyed	
Ohio								
Oberlin	Reservoir	15.0	4.0	Chara	May 24, 1905	2.0	Large numbers were killed	
Indiana								
Anderson	White River			Oscillaria	July 16, 1905		Slight diminution in numbers	
Illinois								
Leclaire	Artificial Lake	23.0	7.0	Spirogyra	July 28, 1905	8.0	Destroyed in 1 day	
Springfield	Lily Pond	0.5	0.2	Conferva Spirogyra	May 24, 1905	8.0	Destroyed	
Colorado								
Denver	Lake in City Park	4.0	1.0	Navicula Anabæna Clathrocystis Aphanizomenon Rotifera	August 10, 1904	2.0	All destroyed in 4 days	
	Marston Lake Reservoir	4 500.0	600.0	Anabæna Synedra Stephanodiscus Ceratium Peridinium	October 6 and 7, 1905	3.7	All destroyed in 4 days	
Montana								
Butte	Basin Creek Reservoir	190.0		Anabæna Asterionella	July 6, 1905	8.3	All destroyed in 8 days	

** Indicates no tastes or odors or fish present before treatment

NOTE. — Reports were received from about twenty other places, where the troublesome organism was merely said to be
treatment was successful in each case, but in thirteen of them the organism reappeared the same year. These places where the

ENGLAND WATER WORKS ASSOCIATION

IN THE USE OF COPPER SULPHATE FOR REMOVING ORGANISMS FROM WATER

(Compiled from statements received from persons who have used this treatment)

Treatment			Reappearance of Organisms in Same Year			Remarks
	Effect					
Organisms	On Tastes and Odors	On Fish	Organism	Length of Time since Last Treatment	Extent	
days	Disappeared in 3 days	None		*		
5 days	Disappeared in 5 days	None	Uroglena Anabæna	4 months		In September, 1903, reservoir again treated as before. Organisms disappeared more slowly than after previous treatments
	None	None				
on { destroyed one			Cosmarium Protococcus Scenedesmus Staurastrum	Developed at once	Large numbers	August 20 the reservoir was again treated with one part copper sulphate to .7 million parts water, which affected the Staurastrum and killed 50 perch August 30 the reservoir was again treated as above but only affected Cosmarium. Protococcus and Scenedesmus were not affected
oyed	Disappeared in 6 days	None	Tabellaria Asterionella	1 month	Large numbers	No further treatment
y destroyed	Improved slightly	None	Anabæna	1 month	Large numbers	Again treated with one part copper sulphate to 8.0 million parts water. Anabæna destroyed and taste and smell disappeared
	Disappeared	Some small bass killed		*		
	**	None				
6 weeks	**	Killed about 5 000 fish — suckers, bass, perch and sunfish				
	Disappeared	None		*		
—		250 000 killed. Essentially small perch and suckers				
oyed, others ed	Improved till Chlamydomonas developed	None	Essentially Chlamydomonas also Diatomaceæ and Chlorophyceæ	4 weeks	Slightly larger numbers	The reservoir was treated as before on August 23, 1904, and all organisms except Chlamydomonas were destroyed. Uroglena appeared in December, 1904
oyed, others ed	Improved permanently	None	Tabellaria Chlamydomonas		Smaller numbers	The reservoir was treated as before on August 26, 1904. Total organisms decreased 45 per cent.
lays	Disappeared	None	Anabæna	2 months	About twice the number present in July	September 1, 1905, reservoir again treated as before. Organisms disappeared in 5 days
	**	**				August 2, 1905, reservoir again treated as before. Retarded growth of Chara, but only destroyed it in spots
lays	Practically eliminated	A few killed				Anabæna reappeared in 1900 and the reservoir was treated again in November. Results not available
	Disappeared in 3 days	In 3 to 6 days killed 33 pickerel, 63 bass, 1 eel and 1 catfish. This was a small percentage of the fish in the lake				
	Disappeared	Few small trout killed		2 or 3 months		
	Disappeared	Considerable number killed, principally catfish		2 or 3 months		
ays	Disappeared	None		2 or 3 months		
ays				*		
ays		None		*		
						Organisms not present in as large numbers in 1903 as in 1904
	**	**	Ulothrix		Small numbers	The water in this basin is changed several times a day, there being a continuous flow through it. Part of 25 pounds of copper sulphate were dragged over the water surface and the remainder hung in the inlet
	Disappeared	Several killed	Fragilaria	4 to 6 weeks	Much smaller numbers	The reservoir was again treated as before and organisms were destroyed
	None	None	Clicha algæ	6 weeks	As in May	The first treatments were made before the algæ had developed in large numbers. Both reservoirs were again treated in the middle of July and all algæ disappeared
	None	None	Clicha algæ	6 weeks	As in May	
	Disappeared	None		*		
	Disappeared		Oscillaria Anabæna	2 months 3 months	Small numbers Large numbers	The reservoir was treated when the Anabæna reappeared in about the same strength as before, destroying the Anabæna almost at once
	Disappeared	**	Not known	3 days	Great numbers	Treated frequently and in greater strength, but no effect was noticed
re killed	None	4 killed				The reservoir was treated as before on July 23 and on August 16 and 21. The Chara were destroyed, but a musty taste continued
in numbers	Improved		Oscillaria	Few days	Abundant	No further treatment. The first treatment was with 400 pounds of copper sulphate distributed 1½ miles up stream from the intake. The river is very sluggish
y	None	None	Spirogyra	1 month	Smaller numbers	No further treatment
	None	None	Conferva	1 week	About one half the number before treatment	The pond was again treated June 2 and twice as strong as before. Organisms destroyed
days						
days	Disappeared in 2 days					
days				*		

* Indicates the non-reappearance of organisms

Blank spaces indicate no data given

y said to be algæ. These have been grouped together, and the following statement is a summary of these results: Of the twenty places having algæ which caused trouble, the es where the algæ reappeared were distributed over the country.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, November 8, 1905.

George Bowers, President, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, L. M. Bancroft, H. K. Barrows, George Bowers, Dexter Brackett, E. C. Brooks, James Burnie, F. H. Carter, J. C. Chase, D. D. Clarke, F. C. Coffin, R. C. P. Coggeshall, M. F. Collins, G. E. Crowell, A. W. Cuddeback, F. F. Forbes, E. V. French, F. L. Fuller, T. C. Gleason, A. S. Glover, R. A. Hale, J. O. Hall, L. M. Hastings, T. G. Hazard, Jr., H. G. Holden, F. S. Hollis, J. L. Howard, W. S. Johnson, Willard Kent, F. C. Kimball, G. A. King, L. P. Kinnicutt, W. W. Locke, D. E. Makepeace, A. D. Marble, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, H. A. Miller, F. L. Northrop, T. W. Norcross, J. B. Putnam, H. E. Royce, C. W. Sherman, W M. Stone, G. H. Snell, G. A. Stacy, J. T. Stevens, H. L. Thomas, W. H. Thomas, J. L. Tighe, D. N. Tower, W. H. Vaughn, C. K. Walker, R. S. Weston, C.-E. A. Winslow, G. E. Winslow, F. E. Winsor. — 60.

Honorary Member.

William T. Sedgwick. — 1.

Associates.

Roy S. Barker; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, W. A. Hersey; International Steam Pump Co., by Samuel Harrison; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates and C. L. Brown; A. P. Smith Mfg. Co., by F. N. Whitcomb; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by Frank L. Northrop and W. F. Hogan; Water Works Equipment Co., by W. H. Van Winkle. — 18.

Guests.

J. D. Ferguson, Scituate, Mass.; Raymond W. Kent, Cambridge, Mass.; J. H. Howland, Supt. Water Works, Honolulu, H. I.; F. E. Adams, Boston; Murray Millikin, Boston. — 5.

[Names counted twice. — 3.]

The following were elected members:

Lewis R. Davis, Pittsburgh, Pa.; Stanley A. Miller, Asst. Engineer Mexican Light & Power Co., Necaxa, Puebla, Mexico; Donald M. Belcher, Sanitary Engineer, Charleston, S. C.; John Hastings Howland, Asst. Superintendent of Public Works and Superintendent of Water Works, Honolulu, H. I.; Alexander Orr, Superintendent of Water Works, Gloversville, N. Y.; Warren U. C. Baton, Asst. Chemist, Washington Aqueduct Filtration Plant, Washington, D. C.; George T. Moore, engaged in sanitary work connected with water supplies, Washington, D. C.; George C. Warren, President Water Commissioners, Saginaw, Mich.; James Lyford Davis, Asst. Engineer, Aqueduct Commission, New York; John Byron Goldsborough, Croton-on-Hudson, N. Y.; E. L. Grimes, Troy, N. Y.; Ernest C. Levy, M.D., Director of Laboratory of Water Department, Richmond, Va.; Jules Breuchaud, Yonkers, N. Y.; Joseph F. Regan, Jr., General Manager Consolidated Water Co., Utica, N. Y.; Albert L. Webster, Civil and Sanitary Engineer, New York City; Theodore D. L. Coffin, in charge of the Long Island Filter Plants, Jamaica, L. I.; H. W. Clark, General Manager and Treasurer of Mattoon Clear Water Co., Mattoon, Ill.; William Naylor, Superintendent of Water Works, Maynard, Mass.

The paper of the afternoon was by Profs. W. T. Sedgwick and C.-E. A. Winslow of the Massachusetts Institute of Technology, on "The Present Relative Responsibility of Public Water Supplies and Other Factors in the Causation of Typhoid Fever." It was followed by a discussion by Mr. E. E. Lochridge, Engineer of the Water Department, Springfield, Mass.; Dr. George Burgess Magrath, Acting Secretary of the State Board of Health; Professor Winslow, Prof. Leonard P. Kinnicutt, Robert S. Weston, Dr. Frederick S. Hollis, and Wm. W. Locke.

Adjourned.

EXECUTIVE COMMITTEE.

BOSTON, MASS., November 8, 1905.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Wednesday, November 8, 1905, at 11.30 A.M.

Present: President George Bowers and Charles W. Sherman, Frank E. Merrill, F. W. Gow, George E. Crowell, George A.

Stacy, L. M. Bancroft, James Burnie, James L. Tighe, and Willard Kent.

The Secretary read the applications for membership from the following persons:

Donald M. Belcher; F. L. Grimes; Alexander Orr; John F. Reagan, Jr.; Albert L. Webster; Jules Breuchaud; John Hastings Howland; Ernest C. Levy, M. D.; Lewis K. Davis; Theodore D. L. Coffin; William Naylor; H. W. Clark; Warren U. C. Baton; Stanley A. Miller; George T. Moore; George C. Warren; James L. Davis; John B. Goldsborough;

and it was voted to recommend the applicants for election.

On motion of Mr. Stacy, seconded by Mr. Tighe, it was voted: That the February meeting of the association be recommended for Ladies' Day.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

OBITUARY.

AURELIUS G. PEASE, water commissioner, Spencer, Mass., died September 20, 1905, at Phœnix, B. C., where he had gone on a vacation trip. He was sixty-eight years of age, and had been in business in Spencer for thirty years. He leaves a wife and one daughter.

Mr. Pease became a member of the New England Water Works Association on June 16, 1886.

BOOK NOTICES.

Report of the New York Bay Pollution Commission: Daniel Lewis, Olin H. Landreth, Myron S. Falk, George A. Soper, Louis L. Tribus, Commissioners. [State of New York, Senate Document No. 39, 1905.] 135 pages and folded map.

The question of the pollution of New York Bay by sewage is obviously one of great importance, and the difficulties in the way of a satisfactory solution, due to the division of jurisdiction between the states of New York and New Jersey, are serious. This commission was appointed in June, 1903, and reported on March 31, 1905. The several members of the Commission took up individually the investigation of branches of the main subject, and their detailed reports are given as appendices to the report of the Commission. Its recommendations are, that the State of New York bring action in the United States Supreme Court against the State of New Jersey and the Passaic Valley District Sewerage Commission, to prevent the discharge of the sewage of that district in the harbor; and that a Metropolitan District Sewerage Commission be appointed to continue the work, and to make comprehensive plans for the sewage disposal of the whole New York Metropolitan District.

Thirty-sixth Annual Report of the State Board of Health of Massachusetts, for the year 1904.

In addition to the advice to cities and towns, and experiments on purification of sewage and water, which are regular features of these reports, the present volume contains a report on examination of public water supplies, covering some seventy-five pages, giving the averages of the chemical analyses of all the water supplies of the state for the last five years, and also grouping the several sources in the order of their chemical constituents, there being a separate table for each of the more important substances shown by chemical analysis, as well as for color, odor, and hardness. The water supply statistics given also contain the consumption of water for all supplies in the state of which records are available, as well as records of rainfall and flow of streams for the year.

CONSTITUTION OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

[*Adopted September 19, 1900; amended September 9, 1903, and March 8, 1905.*]

ARTICLE I.

NAME AND OBJECT.

SECTION 1. The name of this society shall be THE NEW ENGLAND WATER WORKS ASSOCIATION.

SECT. 2. Its objects shall be the advancement of knowledge relating to water works and water supply, and the encouragement of social intercourse among water works men.

ARTICLE II.

SECTION 1. The membership of the Association shall consist of Members, Honorary Members, and Associates.

SECT. 2. Water works superintendents or other executive officers, commissioners or members of Water Boards, hydraulic engineers, sanitarians or other persons qualified to aid in the advancement of knowledge relating to hydraulic questions, shall be eligible as Members.

SECT. 3. Members only shall be eligible to office and entitled to the right to vote.

SECT. 4. Associates shall be firms or representatives of firms engaged in dealing in supplies used by water works.

SECT. 5. Members hereafter elected engaging in the business of furnishing water works supplies shall cease to be Members of the Association and their names shall be transferred to the list of Associates.

SECT. 6. Associates shall be entitled to representation at each meeting of the Association, but shall not be entitled to vote or to take part in any discussion unless permission is given by the meeting.

SECT. 7. Honorary Members shall be men eminent in some line of work connected with hydraulic engineering or water supply.

SECT. 8. Members shall be classed as Resident or Non-Resident; the former comprising residents of the New England States, all others being Non-Resident Members.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

SECTION 1. An application for admission to the Association as Member or Associate shall embody a concise statement of the candidate's qualifica-

tions for membership, and shall be endorsed by two Members of the Association. All applications for membership presented to the Association for action must be accompanied by the proper initiation fee and dues for whole or fractional part of current year in which application is presented.

SECT. 2. Applications for membership shall be considered by the Executive Committee, who shall present them to the Association for ballot, provided a majority are in favor of such action.

SECT. 3. Election to membership shall be by ballot, and shall require two thirds of the ballots cast.

SECT. 4. Members and Associates elect shall subscribe their names to the Constitution by signing a form to be furnished by the Secretary.

SECT. 5. The annual membership dues shall be payable in advance on the date of the annual meeting in January. At the expiration of ten months after the annual meeting, the Secretary shall notify each member who has not paid his dues for the current year, that unless the same are paid within thirty days his membership in the Association shall cease; and if said dues are not paid within said period, the Secretary shall drop the name of said member from the membership roll. The Executive Committee may, however, at its discretion reinstate said person on the payment of all arrears.

SECT. 6. A member of any grade may withdraw from the Association by giving written notice to the Secretary and settling all indebtedness to the Association.

SECT. 7. A member of any grade may be expelled from the Association upon the recommendation of the Executive Committee, adopted by a two-thirds vote of the members present and voting at any regular meeting.

ARTICLE IV.

DUES.

SECTION 1. The Initiation Fee shall be —

For Resident Members . . .	$5.00
For Non-Resident Members . .	3.00
For Associates	10.00

SECT. 2. The Annual Dues shall be —

For Members	$3.00
For Associates	15.00

SECT. 3. A person transferred from the grade of Member to that of Associate shall not be assessed an additional initiation fee, but shall be liable for dues as an Associate.

SECT. 4. Three dollars of the dues of each Member or Associate, or such portion thereof as may be required, shall annually be applied to payment of a subscription to THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

ARTICLE V.

OFFICERS.

SECTION 1. The officers of this Association shall be a President, six Vice-Presidents, not more than three of whom shall be residents of the same State, a Secretary, and a Treasurer; these, together with the Editor and Advertising Agent of THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION and three other Members, shall constitute the Executive Committee, in whom the government of the Association shall be vested.

SECT. 2. The term of office of all officers and committees shall be one year, but shall continue until their successors are duly elected.

SECT. 3. There shall also be a Finance Committee of three Members of the Association other than members of the Executive Committee.

SECT. 4. All officers and committees shall assume their duties immediately after the close of the meeting at which they have been elected.

ARTICLE VI.

DUTIES OF OFFICERS.

SECTION 1. The President shall have a general supervision of the affairs of the Association. He shall preside at meetings of the Association and of the Executive Committee. In case of his absence or a vacancy in his office, the Vice-Presidents in order of seniority shall discharge his duties.

SECT. 2. The Executive Committee shall have full control of the management of the Association, subject to the action of the Association at any meeting. They shall make the necessary arrangements for all meetings, and shall have power to expend the funds of the Association, provided that no indebtedness shall be incurred in excess of the funds in the hands of the Treasurer. All questions in Executive Committee shall be decided by a majority vote, and six members shall be a quorum. The Executive Committee shall hold meetings at the call of the President, or, in his absence or inability to serve, at the call of the senior Vice-President.

SECT. 3. The Secretary shall conduct the official correspondence of the Association, shall collect and receipt for all fees and dues, and transmit the same to the Treasurer quarterly, taking his receipt therefor; he shall issue notices of all meetings of the Association at a date not less than two weeks prior to the time appointed for such meetings. He shall make a report to the Association at the annual meeting of the general condition of the Association and especially of changes in the membership.

SECT. 4. The Treasurer shall receive from the Secretary all moneys collected by him for the Association, giving his receipt therefor, and shall pay all demands against the Association when approved by the President. He shall keep a proper account of all receipts and expenditures, and shall make a report to the Association, at the annual meeting, of his doings as Treasurer during the year preceding, together with a statement of the financial standing of the Association. He shall deposit all funds received in such place of deposit as may be approved by the Executive Committee. All orders for withdrawal of funds and checks for disbursements shall be signed by the Treasurer and countersigned by the President.

SECT. 5. The Finance Committee shall meet on or before the day of the annual meeting, and shall audit the accounts of the Secretary and Treasurer. They shall hold such other meetings as the interests of the Association may require.

SECT. 6. The proceedings of the Association shall be published as THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, which shall be issued quarterly, under the direction of a Board of Editors, consisting of the President and Secretary, *ex officiis*, and the Editor and Advertising Agent chosen by ballot. The Journal shall contain such portion of the record of any meeting as the Board of Editors may deem it expedient to publish, as well as any other articles which they shall consider of interest to the Association.

SECT. 7. The Editor of THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION shall, under the direction of the Board of Editors, keep and prepare for publication all matters intended to be printed in the Journal, and shall act as the executive officer of the Board of Editors. He shall present a report at the annual meeting, showing in detail the cost of publication of the Journal and the receipts from advertising and subscriptions.

ARTICLE VII.

NOMINATION AND ELECTION OF OFFICERS.

SECTION 1. At the business meeting during the annual convention the Association shall elect or appoint, in such manner as may be approved by the meeting, a Nominating Committee of five Members, who shall present a report before the first day of November, in the form of a list of nominations for officers for the ensuing year. This report shall be printed and mailed by the Secretary to the membership of the Association.

SECT. 2. At any time before December 1, any ten or more Members of the Association may send to the Secretary additional nominations signed by such Members.

SECT. 3. The Secretary shall issue a printed ballot on the fifteenth day of December, which shall contain the nominations made by the Nominating Committee and such other nominations as may have been received by him in accordance with Section 2. This ballot shall be mailed to all Members entitled to vote.

SECT. 4. Ballots may be sent by mail to the Secretary or handed to him directly. They must be enclosed in two sealed envelopes, and the outer envelope shall be endorsed by the voter's signature.

SECT. 5. The polls shall be closed one hour after the time of opening the Annual Meeting, and the ballots shall be canvassed by tellers appointed by the presiding officer. The persons receiving the highest number of votes for the offices for which they are candidates shall be declared elected.

ARTICLE VIII.

MEETINGS.

SECTION 1. A Convention of the Association for the reading and discussion of papers and for social intercourse shall be held annually at such time and place as may be determined by the Executive Committee.

SECT. 2. There shall be two general business meetings of the Association each year; first, the annual meeting, which shall be held in Boston on the second Wednesday in January, and at which the annual reports for the year ending December 31 shall be presented, and the ballot for officers canvassed; and second, a business meeting during the annual convention.

SECT. 3. In addition to the above, business meetings shall be held on the second Wednesday of the months of November, December, February, and March, and, at the discretion of the Executive Committee, in June.

SECT. 4. At any business meeting of the Association, twenty Members shall constitute a quorum.

SECT. 5. All regular meetings of the Association, except the annual convention, shall be held in Boston, unless otherwise voted by the Executive Committee.

SECT. 6. Special meetings of the Association may be held at the call of the President. At special meetings no applications for membership shall be considered, and no business shall be transacted unless announced in the call for the meeting and on the recommendation of the Executive Committee.

SECT. 7. Meetings of the Executive Committee shall be held before each business meeting of the Association and at such other times as the President may deem necessary.

ARTICLE IX.

AMENDMENTS.

SECTION 1. Proposed amendments to this Constitution must be submitted in writing to the Executive Committee, and shall be presented to the Association at a regular meeting, if so decided by vote of the committee. It shall be the duty of the Executive Committee to bring before the Association any proposed amendment at the written request of ten Members.

SECT. 2. Announcements of a proposed amendment which is recommended by the Executive Committee, or by ten Members of the Association, shall be given by printing the amendment in the notices of the regular meeting. A two-thirds vote of the Members present and voting shall be necessary for the adoption of an amendment.

OFFICERS

OF THE

New England Water Works Association.

1905.

PRESIDENT.

GEORGE BOWERS.

VICE-PRESIDENTS.

JAMES BURNIE. FREDERICK W. GOW.
FRANK A. ANDREWS. EDMUND W. KENT.
GEO. E. CROWELL. CHAS. E. CHANDLER.

SECRETARY. TREASURER.

WILLARD KENT. LEWIS M. BANCROFT.

EDITOR. ADVERTISING AGENT.

CHARLES W. SHERMAN. ROBERT J. THOMAS.

ADDITIONAL MEMBERS OF EXECUTIVE COMMITTEE.

FRANK E. MERRILL. GEORGE. A. STACY.
JAMES L. TIGHE.

FINANCE COMMITTEE.

W. W. ROBERTSON. R. C. P. COGGESHALL.
HARRY L. THOMAS.

PAST PRESIDENTS.

*James W. Lyon, 1882–83.
Frank E. Hall, 1883–84.
*George A. Ellis, 1884–85.
Robert C. P. Coggeshall, 1885–86.
*Henry W. Rogers, 1886–87.
*Edwin Darling, 1887–88.
*Hiram Nevons, 1888–89.
Dexter Brackett, 1889–90.
*Albert F. Noyes, 1890–91.
Horace G. Holden, 1891–92.
George F. Chace, 1892–93.
*George E. Batchelder, 1893–94.
George A. Stacy, 1894–95.
Desmond FitzGerald, 1895–96.
*John C. Haskell, 1896–97.
Willard Kent, 1897–98.
Fayette F. Forbes, 1898–99.
Byron I. Cook, 1899–1900.
Frank H. Crandall, 1901.
Frank E. Merrill, 1902.
Charles K. Walker, 1903.
Edwin C. Brooks, 1904.

* Deceased.

LIST OF MEMBERS,

WITH ADDRESS AND DATE OF ELECTION.

[*Corrected to March 15, 1905.*]

NAME.	Date of Election.
Adams, John D. Supt. Water Works, Provincetown, Mass.	Sept. 8, 1897
Agnew, Samuel A. Supt. Scituate Water Works, North Scituate, Mass.	Jan. 14, 1903
Allen, Charles A., C. E. 44 Front Street, Worcester, Mass.	June 16, 1886
Allen, Kenneth Engineer and Supt. Water Dept., Atlantic City, N. J.	June 11, 1902
Alvord, John W. 127 Hartford Building, Chicago, Ill.	Nov. 12, 1902
Amyot, John A., M. B. Bacteriologist to the Provincial Board of Health of Ontario, 305 Joseph Street, Toronto, Canada.	Nov. 14, 1900
Anderson, J. M. 246 Pleasant Street, Worcester, Mass.	Jan. 9, 1901
Andrews, Frank A. Asst. Supt. Pennichuck Water Works, Nashua, N. H.	Dec. 14, 1887
Anthony, Charles, Jr. East London, Cape Colony, South Africa.	June 12, 1901
Appleton, Francis E. Paymaster Locks & Canals Co., Lowell, Mass.	Dec. 8, 1897
Atkinson, Edward President Boston Manufacturers Mutual Fire Insurance Company, 31 Milk Street, Boston, Mass.	Nov. 9, 1904
Babcock, Stephen E. Water Works and Hydraulic Engineer, Mann Building, Utica, N. Y.	June 12, 1886
Bacot, R. C., Jr. Supt. Meter Dept., P. O. Box 221, Port Chester, N. Y.	Dec. 12, 1888
Bagnell, Richard W. Plymouth, Mass.	Dec. 21, 1882
Bailey, E. W. City Engineer, Somerville, Mass.	Dec. 11, 1895
Bailey, Frank S. 177 Washington Street, Weymouth, Mass.	Sept. 8, 1897
Bailey, George I. Consulting Engineer, 1199 Fulton Avenue, New York City.	Dec. 14, 1892
Baker, M. N. Associate Editor *Engineering News*, 220 Broadway, New York City.	Sept. 18, 1901
Baldwin, Charles H. 159 Franklin Street, Boston, Mass.	June 17, 1887

Name.	Date of Election.
Bancroft, Lewis M. Supt. Water Works, Reading, Mass.	Jan. 8, 1890
Barbour, Frank A., C. E. 1120 Tremont Building, Boston, Mass.	Jan. 10, 1894
Barnes, Roland D., C. E. Bristol, Conn.	June 14, 1899
Barnes, T. Howard Civil and Municipal Engineer, San José, Costa Rica, Central America.	Sept. 9, 1903
Barnes, William T. 773 Broadway, Boston, Mass.	Nov. 11, 1903
Barrows, Harold K. 6 Beacon Street, Rooms 808-9, Boston, Mass.	Sept. 11, 1902
Barrus, George H. Consulting Steam Engineer, 12-20 Pemberton Building, Pemberton Square, Boston, Mass.	Jan. 14, 1891
Bartholomew, Jeremiah H. Supt. Water Works, 100 Main Street, Ansonia, Conn.	Feb. 12, 1902
Bartlett, Charles H., C. E. 607 Pemberton Building, Boston, Mass.	Feb. 8, 1893
Bassett, Carroll Ph. Treasurer Water Co., Summit, N. J.	June 13, 1889
Bassett, George B., C. E. 363 Washington Street, Buffalo, N. Y.	Sept. 10, 1897
Batchelder, George W. Water Commissioner, Worcester, Mass.	June 14, 1899
Bates, Hon. Theodore C. 29 Harvard Street, Worcester, Mass.	Jan. 10, 1894
Beals, Joseph E. Supt. Water Works, Middleboro, Mass.	June 16, 1886
Beardsley, Joseph C. 1200 Schofield B'ld'g, Cleveland, Ohio.	Sept. 18, 1901
Beasom, C. B., C. E. 248 Tremont Street, Newton, Mass.	Dec. 12, 1894
Begbie, F. K. Supt. Water Works, Lindsay, Ont.	Sept. 10, 1903
Bemis, Edward W. Supt. Water Works, Cleveland, Ohio.	Nov. 13, 1901
Benzenberg, G. H. Milwaukee, Wis.	June 9, 1892
Berry, Fred D. Secretary Board of Water Commissioners, Hartford, Conn.	Sept. 9, 1903
Berry, W. W. Supt. Water Works, Centerville, Iowa.	Jan. 11, 1905
Bettes, Charles R. Chief Engineer Queen's County Water Co., Far Rockaway, N. Y.	Dec. 9, 1896
Betton, James M. 10 East 16th Street, New York City.	Jan. 8, 1902

Name.	Date of Election.
Bigelow, James F. City Engineer, Marlboro, Mass.	Sept. 11, 1895
Bird, Tyler H. Supt. Water Co., Belfast, Me.	Sept. 9, 1903
Birmingham, Joseph M. President Board of Water Commissioners, Hartford, Conn.	Sept. 9, 1903
Bisbee, Forrest E. Supt. Water Works, Auburn, Me.	Sept. 11, 1895
Bishop, George H., C. E. 129 Main Street, Middletown, Conn.	June 16, 1886
Bishop, Watson L. Supt. Water Works, Dartmouth, N. S.	March 8, 1893
Blackmer, James W. Supt. Water Works, Beverly, Mass.	March 8, 1899
Blagden, H. R. C. Chief Engineer Alexandria Water Works, Alexandria, Egypt.	Sept. 9, 1903
Blossom, William L., C. E. 355 Washington Street, Brookline, Mass.	Dec. 13, 1893
Blunt, H. N. Asst. Supt. Palmer Water Co., Palmerton, Pa.	June 11, 1902
Boggs, Edward M. Consulting Civil and Hydraulic Engineer, Care of Oakland Transit, Oakland, Cal.	Dec. 11, 1889
Bolling, George E. Chemist of Sewer Dept., and City Bacteriologist, 17 Gifford Street, Brockton, Mass.	Dec. 10, 1902
Bowers, George City Engineer, Lowell, Mass.	March 9, 1892
Bowker, Charles L. Supt. Brunswick and Topsham Water District, Brunswick, Me.	Nov. 9, 1904
Brackett, Dexter Engineer Distribution Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	April 21, 1885
Brigham, Charles Chairman Watertown Water Commissioners, 12 Bosworth Street, Boston, Mass.	Feb. 14, 1900
Brinsmade, Daniel S. President and Engineer Ousatonic Water Co., Birmingham, Conn.	Sept. 19, 1883
Brooks, Edwin C. Supt. Water Works, Cambridge, Mass.	Feb. 10, 1897
Brooks, Fred. 31 Milk Street, Boston, Mass.	Feb. 8, 1899
Brown, A. W. F. Water Registrar, Fitchburg, Mass.	June 17, 1887
Brown, Edmund Engineer and Supt. Norfolk Water Co., Norfolk, Conn.	Feb. 12, 1902
Brown, George S. Supt. Water Co., Danielson, Conn.	Sept. 9, 1903

Name.	Date of Election.
Brown, J. Henry 3 Tremont Street, Charlestown, Mass.	Sept. 19, 1883
Brown, Walter I. Water Registrar, Bangor, Me.	June 11, 1896
Brush, William W. Room 41, Municipal Building, Brooklyn, N. Y.	Feb. 12, 1902
Bucknam, George A. P. Supt. Water Works, Norwood, Mass.	June 10, 1891
Burley, Harry B. 31 Milk Street, Room 55, Boston, Mass.	Dec. 14, 1892
Burnham, Albert S. Supt. Water Co., Revere, Mass.	June 13, 1888
Burnie, James Supt. Water Co., Biddeford, Me.	June 11, 1890
Burns, Clinton S. 409 Postal-Telegraph Building, Kansas City, Mo.	Dec. 12, 1900
Burr, William H. Professor of Civil Engineering, Columbia University, and Consulting Engineer, New York City.	Feb. 16, 1894
Bush, Edward W., C. E. Ætna Life Building, Hartford, Conn.	Feb. 13, 1895
Butler, J. Allen Supt. Portland Water Co., Portland, Conn.	June 10, 1891
Cairns, R. A. City Engineer, Waterbury, Conn.	Feb. 13, 1895
Canals, J. A., C. E. P. O. Box 436, San Juan, Porto Rico.	Sept. 9, 1902
Carpenter, L. Z. Attleboro, Mass.	Dec. 13, 1899
Carroll, Fred B. Rumford Falls, Me.	Dec. 12, 1888
Carter, Frank H. Civil Engineer, 14 Beacon Street, Boston, Mass.	Feb. 10, 1904
Cassell, George Supt. Water Works, Chelsea, Mass.	March 8, 1899
Caulfield, John Secretary Water Works, St. Paul, Minn.	Dec. 8, 1897
Cavanagh, John T. 4 Willis Street, Dorchester, Mass.	Feb. 8, 1893
Chace, George F. Supt. Framingham Water Co., South Framingham, Mass.	June 13, 1888
Chadbourne, E. J. 62 Prospect Avenue, Wollaston Heights, Mass.	June 18, 1885
Chandler, Charles E. City Engineer, 161 Main Street, Norwich, Conn.	June 17, 1887
Chandler, Prof. Charles F. 51 East 54th Street, New York City.	Dec. 12, 1888
Chapin, G. L. Water Commissioner, Lincoln, Mass.	March 10, 1897
Chapman, Benjamin R. Asst. Engineer, Brockton, Mass.	Feb. 9, 1898

Name.	Date of Election.
Chase, John C. Chief Engineer Water Works Co., Derry, N. H.	June 19, 1884
Churchill, Percival M. Engineer U. S. Reclamation Service, Chamber of Commerce Building, Denver, Col.	Jan. 14, 1903
Churchill, John W. Water Commissioner, Plymouth, Mass.	Jan. 14, 1903
Clapp, Sidney K. Asst. Engineer U. S. Geological Survey, 179 Boston Street, Boston, Mass.	Jan. 10, 1900
Clark, Frederick W. Newton Highlands, Mass.	Jan. 11, 1893
Clark, Harry W. Chemist Mass. State Board of Health, State House, Boston, Mass.	March 14, 1894
Clark, S. Frederic Water Commissioner, North Billerica, Mass.	March 8, 1899
Clarke, David Dexter Engineer Water Board, City Hall, Portland, Ore.	Nov. 12, 1902
Clarke, E. W. Asst. Engineer Isthmian Canal Commission, Cristobal, Canal Zone.	Jan. 10, 1894
Cleveland, W. F. Sewer Commissioner, Brockton, Mass.	June 9, 1892
Codd, William F. Supt. Wannacomet Water Co., Nantucket, Mass.	June 21, 1885
Coffin, Freeman C. Civil and Hydraulic Engineer, 53 State Street, Boston, Mass.	Feb. 13, 1889
Coggeshall, R. C. P. Supt. Water Works, New Bedford, Mass.	June 21, 1882
Cole, D. W., C. E. Cody, Wyoming.	March 14, 1900
Cole, Edward S. 133 Bellevue Avenue, Upper Montclair, N. J.	Jan. 13, 1904
Cole, F. M. Meter Inspector, Brockton Water Works, Brockton, Mass.	Feb. 10, 1897
Collins, Lewis P. Care Derryfield Co., Manchester, N. H.	Dec. 12, 1894
Collins, Michael F. Supt. Water Works, Lawrence, Mass.	Sept. 18, 1901
Colver, Courtland E. Supt. Water Co., Groton, Conn.	Jan. 14, 1903
Conard, William R. 1004 High Street, Burlington, N. J.	Nov. 12, 1902
Connell, Michael A. Supt. Water Works, St. Hyacinthe, P. Q.	Dec. 13, 1893
Connor, Virgil R. Trustee Kennebec Water District, Fairfield, Me.	Feb. 10, 1904
Cook, Byron I. Woonsocket, R. I.	March 13, 1889

Name.	Date of Election.
Cook, John H. Hydraulic Engineer, S. U. M., 158 Ellison Street, Paterson, N. J.	Feb. 8, 1905
Crandall, F. H. Supt. and Treas. Water Works, Burlington, Vt.	June 13, 1888
Crandall, George K. Civil Engineer, New London, Conn.	June 9, 1892
Crawford, J. W. Clerk of Water Board, Lowell, Mass.	June 12, 1896
Crosby, Everett U. 76 William Street, New York City.	March 4, 1900
Crowell, George E. President Water Works, Brattleboro, Vt.	June 15, 1893
Crowley, Robert J. President Lowell Water Board, 52 Mt. Washington Street, Lowell, Mass.	Sept. 14, 1904
Cuddeback, Allan W. Asst. Engineer Passaic Water Co., 109 Washington Street, Paterson, N. J.	Jan. 10, 1900
Cummings, Louis B. Clerk Board of Public Works, Pittsfield, Mass.	Feb. 12, 1902
Daboll, L. E., C. E. New London, Conn.	Jan. 10, 1894
Dana, Gorham Manager Underwriters' Bureau of New England, 93 Water Street, Boston, Mass.	Dec. 9, 1903
Davis, Carleton E. Sanitary Engineer Isthmian Canal Commission, Ancon, Canal Zone.	March 12, 1902
Davis, F. A. W. Pres. and Treas. Water Co., Indianapolis, Ind.	June 17, 1887
Davis, J. M. Rutland, Vt.	Sept. 13, 1895
Davison, George S. Sec'y and Gen. Manager Monongahela Street Railway Co., 512 Smithfield Street, Pittsburg, Pa.	June 15, 1894
Dean, Arthur W. 135 Main Street, Nashua, N. H.	March 8, 1899
Dean, Francis W. Mechanical Engineer, 53 State Street, Boston, Mass.	June 11, 1890
Dean, Seth, C. E. Glenwood, Iowa.	Dec. 12, 1888
Dean, William H. Water Analyst, Wilkesbarre, Pa.	Sept. 10, 1898
DeBerard, Wilford W. Care Board of Public Works, Harrisburg, Pa.	Sept. 19, 1900
Denman, A. N. Des Moines, Iowa.	June 16, 1886
Desmond, J. J. President Water Board, Lawrence, Mass.	Sept. 9, 1903

Name.	Date of Election.
Devereux, A. M. Treas. and Manager Castine Water Co., Castine, Me.	Feb. 12, 1902
Diven, J. M. Supt. Light and Water Co., Charleston, S. C.	June 16, 1886
Doane, A. O. Engineering Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Jan. 8, 1896
Doherty, M. J. Engineer Metropolitan Water Works, 125 West Central Street, Natick, Mass.	June 10, 1903
Doten, Leonard S. Civil Engineer, Quartermaster Dept. U. S. Army, 170 Summer Street, Boston, Mass.	Jan. 8, 1902
Dotten, William T. Supt. Water Works, Winchester, Mass.	June 21, 1882
Doyle, John General Foreman Water Dept., 7 Townsend Street, Worcester, Mass.	Feb. 8, 1905
Drake, Albert B., C. E. 164 William Street, New Bedford, Mass.	April 21, 1885
Drake, Charles E., C. E. New Bedford, Mass.	Jan. 8, 1890
Dunbar, E. L. Supt. Water Works, Bay City, Mich.	June 9, 1892
Dwelley, Edwin F. 144 Nahant Street, Lynn, Mass.	Sept. 18, 1901
Dyer, Eben R. Supt. of Distribution, Portland, Me.	June 11, 1890
Esrdley, B. A. Supt. Pacific Improvement Co. Water Works, Pacific Grove, Monterey County, Cal.	June 15, 1893
Earl, George Goodell Supt. Sewerage and Water Board, 1307 Valence Street, New Orleans, La.	Feb. 11, 1903
Eaton, Harvey D. Waterville, Me.	Sept. 9, 1903
Eddy, Harrison P. Supt. Sewer Department, City Hall, Worcester, Mass.	June 15, 1894
Eglee, Charles H. Hydraulic Engineer, 176 Devonshire Street, Boston, Mass.	June 13, 1889
Eldredge, Edward D. Supt. Onset Water Co., Onset, Mass.	Feb. 14, 1900
Ellis, John W. Civil Engineer, Woonsocket, R. I.	Dec. 11, 1889
Ellis, Robert N. Manager Water Works, Jacksonville, Fla.	June 10, 1903
Ellsworth, Emory A. Civil and Hydraulic Engineer, Holyoke, Mass.	June 10, 1896
Evans, George E. Civil Engineer, 95 Milk Street, Boston, Mass.	Feb. 14, 1888
Evans, Myron Edward Civil Engineer, 22 Pine Street, New York City.	June 13, 1900

Name.	Date of Election.
Falcon, Joseph G. Submarine Engineer, Evanston, Ill.	June 12, 1901
Fales, Frank L. Asst. Engineer, Engineering Dept., Board of Trustees, Commissioners Water Works, Cincinnati, Ohio.	Dec. 13, 1893
Fanning, John T. Consulting Engineer, Kasota Block, Minneapolis, Minn.	April 21, 1885
Farnham, Elmer E. Supt. Water Works, Box 109, Sharon, Mass.	Dec. 11, 1889
Farnum, Loring N. Civil and Hydraulic Engineer, 53 State Street, Boston, Mass.	Dec. 13, 1893
Fels, August Water Commissioner, Lowell, Mass.	Sept. 13, 1899
Felton, B. R. Civil Engineer, Tremont Building, Boston, Mass.	June 9, 1892
Felton, Charles R. City Engineer, City Hall, Brockton, Mass.	Feb. 16, 1894
Ferguson, John N. Asst. Engineer Charles River Basin Commission, 367 Boylston Street, Boston, Mass.	Dec. 14, 1898
Finigan, Elizabeth M. Supt. and Sec'y Lyons Water Works Co., Lyons, N. Y.	Sept. 14, 1904
Fisher, Edwin A. City Engineer, 16 Reynolds Street, Rochester, N. Y.	Nov. 13, 1901
Fiske, Henry A. 93 Water Street, Boston, Mass.	Sept. 18, 1901
Fitch, Jasper A. Supt. Water Co., Manchester, Conn.	June 12, 1890
Flinn, Alfred D. General Inspector, Engineering Dept., Croton Aqueduct, 839 West End Avenue, New York City.	Dec. 10, 1902
Flinn, Richard J., M. E. West Roxbury Station, Boston, Mass.	Sept. 11, 1895
Flynn, John H. 710 Albany Street, Boston, Mass.	June 11, 1902
Fobes, A. A. Engineer Board of Public Works, Pittsfield, Mass.	Feb. 13, 1895
Folwell, A. Prescott Professor of Sanitary and Hydraulic Engineering, Lafayette College, Easton, Pa.	June 15, 1893
Forbes, Fred B. 502 State House, Boston, Mass.	June 14, 1899
Forbes, F. F. Supt. Water Works, Brookline, Mass.	Jan. 29, 1885
Forbes, Murray Manager Westmoreland Water Co., Greensburgh, Pa.	Feb. 11, 1891
Foss, William E. Division Engineer Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Foster, E. H. Mechanical Engineer, 126 Liberty Street, New York City.	Jan. 14, 1903

Name.	Date of Election.
Foyé, Andrew E., C. E. Acting Chief Engineer Dept. of Highways and Viaducts, Greater New York, 11 Broadway, New York City.	Dec. 12, 1894
Freeman, John R. President Factory Insurance Co.'s, 812 Banigan Bldg., Providence, R. I.	Dec. 12, 1888
French, A. M. Water Commissioner, Holyoke, Mass.	Sept. 9, 1903
French, D. W. Supt. Hackensack Water Co., Box 98, Weehawken, N. J.	June 9, 1892
French, Edward V. Insurance Inspector, 31 Milk Street, Boston, Mass.	Sept. 10, 1897
Fuller, Andrew D. 3 Hamilton Place, Boston, Mass.	Dec. 13, 1899
Fuller, Frank L. Civil Engineer, 12 Pearl Street, Boston, Mass.	June 16, 1886
Fuller, George W. 170 Broadway, New York City.	March 8, 1893
Fuller, William B. Care Hering & Fuller, 170 Broadway, New York City.	Feb. 12, 1902
Gage, Stephen DeM. Biologist Mass. State Board of Health, Lawrence, Mass.	Jan. 10, 1900
Gaylord, Elbert W. Supt. Bristol Water Co., Bristol, Conn.	Feb. 8, 1905
Geer, Harvey M. Civil Engineer, Ballston Spa, N. Y.	Sept. 10, 1897
Gerhard, William Paul Civil Engineer and Consulting Engineer for Sanitary Works, 33 Union Square, West, New York City.	Dec. 12, 1888
Gerrish, William B. Supt. and Engineer Water Works, Oberlin, Ohio.	Dec. 14, 1892
Gerry, L. L. Civil Engineer, Stoneham, Mass.	Jan. 29, 1885
Getchell, Ira E. Trustee Kennebec Water District, Waterville, Me.	Feb. 10, 1904
Gibbs, Harry F. 106 Pond Street, Natick, Mass.	Jan. 11, 1899
Gilbert, Julius C. Water Registrar and Treas. Water Works, Whitman, Mass.	June 15, 1894
Gilderson, D. H. Supt. Water Works, Haverhill, Mass.	Sept. 11, 1895
Gleason, Fred B. Inspector, Marlboro, Mass.	Sept. 13, 1895
Gleason, T. C. Supt. Water Works, Ware, Mass.	June 15, 1894
Glover, Albert S. Tremont Temple Building, Boston, Mass.	June 21, 1882
Golding, Frank H. Manager and Supt. Branford Lighting and Water Co., Branford, Conn.	Dec. 10, 1902

Name.	Date of Election.
Goldthwait, W. J. Marblehead, Mass.	June 11, 1890
Goodell, Jerome W. Water Commissioner, Burlington, Vt.	Sept. 18, 1901
Goodnough, B. F. South Street, Brookline, Mass.	Feb. 12, 1902
Goodnough, X. H. Engineer State Board of Health, Room 140, State House, Boston, Mass.	Jan. 14, 1891
Gould, Amos A. Water Commissioner, Leicester, Mass.	March 11, 1896
Gould, John A. Chief Engineer Brookline and Dorchester Gas Light Companies, 24 West Street, Boston, Mass.	June 14, 1888
Gow, Frederick W. Supt. Water Works, Medford, Mass.	June 11, 1890
Gowing, E. H., C. E. 12 Pemberton Square, Boston, Mass.	April 21, 1885
Graham, James W. Supt. Meter Dept., Portland Water Co., Portland, Me.	Sept. 13, 1895
Green, Harry E. With Kennebec Water District, Waterville, Me.	Sept. 14, 1904
Greetham, H. W. Local Manager Orlando Water and Sewerage Co., Orlando, Fla.	June 13, 1889
Gregory, John H. Principal Assistant Engineer Water Filtration and Sewage Disposal, Board Public Service, Columbus, Ohio.	Nov. 9, 1904
Griffin, J. William Care N. Y. & N. J. Water Co., Arlington, N. J.	Dec. 12, 1900
Gubelman, F. J., C. E. 792 Montgomery Street, Jersey City, N. J.	March 11, 1896
Haberstroh, Charles E. Asst. Supt. Metropolitan Water Works, South Framingham, Mass.	Jan. 10, 1900
Hague, Charles A. Consulting Engineer, 52 Broadway, New York City.	Nov. 9, 1904
Hale, Richard A. Principal Assistant Engineer Essex Co., Lawrence, Mass.	Feb. 14, 1888
Hale, Richard K. Chestnut Hill Avenue, Brookline, Mass.	Jan. 11, 1905
Hall, A. S. Supt. Kennebec Water District, Waterville, Me.	Sept. 14, 1904
Hall, Frank E. 92 West Street, Worcester, Mass.	June 21, 1882
Hall, Hon. John O. 1230 Hancock Street, Quincy, Mass.	Dec. 12, 1900
Hammatt, E. A. W. Civil Engineer, Hyde Park, Mass.	June 17, 1887
Hammond, J. C., Jr. Sec'y and Treas. Rockville Water and Aqueduct Co., Rockville, Conn.	Jan. 11, 1888

Name.	Date of Election.
Hapgood, Lyman P. Supt. Athol Water Co., Athol, Mass.	Nov. 14, 1900
Hardy, J. D. Supt. Water Works, Holyoke, Mass.	March 9, 1898
Harlow, James H. 2 Pleasant Street, Room 207, Baltimore, Md.	Sept. 10, 1897
Hart, Edward W. General Manager Water Works, Council Bluffs, Iowa.	June 10, 1891
Hart, George H. Supt. Water Works, Maynard, Mass.	Feb. 12, 1902
Hart, William H. Asst. Engineer Bridgeport Hydraulic Co., 323 Water Street, Bridgeport, Conn.	March 12, 1902
Hartwell, David A. City Engineer, Fitchburg, Mass.	Feb. 16, 1894
Hastings, L. M. 26 Dana Street, Cambridge, Mass.	June 13, 1889
Hastings, V. C. Supt. Water Works, Concord, N. H.	June 10, 1886
Hatch, S. S. Water Commissioner, South Norwalk, Conn.	June 11, 1896
Hathaway, A. R. Water Registrar, Springfield, Mass.	June 10, 1891
Hawes, Louis E. Civil and Hydraulic Engineer, 101 Tremont Street, Boston, Mass.	Dec. 12, 1888
Hawes, William B. Water Commissioner, Fall River, Mass.	June 15, 1894
Hawkes, George W. Supt. Meter Dept., 182 Newbury Street, Portland, Me.	Sept. 14, 1904
Hawks, William E. Bennington, Vt.	Dec. 12, 1894
Hawley, W. C. Chief Engineer and General Superintendent Pennsylvania Water Co., Wilkinsburg, Pa.	Sept. 8, 1897
Haywood, Elisha F. Water Commissioner, Woburn, Mass.	March 9, 1904
Hazard, T. G., Jr. Civil Engineer, Narragansett Pier, R. I.	June 15, 1894
Hazen, Allen Civil Engineer, 220 Broadway, New York City.	June 9, 1892
Heermans, Harry C. Supt. Water Works, Corning, N. Y.	June 16, 1886
Heffernan, D. A. Supt. Milton Water Works, Milton, Mass.	Nov. 12, 1902
Helme, Bernon E. Manager Water Co., Kingston, R. I.	Sept. 9, 1903
Hering, Rudolph Hydraulic, Civil, and Sanitary Engineer, 170 Broadway, New York City.	June 17, 1887
Herschel, Clemens Hydraulic Engineer, 2 Wall Street, Room 68, New York City.	Feb. 10, 1892

Name.	Date of Election.
Hill, Albert F. Supt. Pawtuxet Valley Water Co., Phenix, R. I.	Nov. 11, 1903
Hill, John W. Chief Engineer Bureau of Filtration, Philadelphia, Pa.	Sept. 9, 1902
Hill, William R. 280 Broadway, New York City.	June 9, 1892
Hodgdon, Frank W. Engineer Mass. Harbor and Land Commission, 131 State House, Boston, Mass.	June 12, 1895
Holden, Horace G. Supt. Pennichuck Water Works, Nashua, N. H.	June 21, 1882
Hollis, Frederick S. Instructor in Chemistry, Yale Medical School, New Haven, Conn.	Dec. 8, 1897
Hook, G. S. Civil Engineer, 705 Union Street, Schenectady, N. Y.	Sept. 13, 1899
Hopkins, Charles C., C. E. Rome, N. Y.	March 10, 1897
Horton, Robert E. Hydraulic Engineer, 75 Arcade Building, Utica, N. Y.	Nov. 12, 1902
Horton, Theodore Resident Engineer, 47 E. Market Street, York, Pa.	June 11, 1902
Howard, John L. Div. Engineer Charles River Basin Commission, 367 Boylston Street, Boston, Mass.	Jan. 10, 1900
Howell, David J. Civil Engineer, 605 12th Street, N. W., Washington, D. C.	Dec. 10, 1902
Hubbard, Winfred D. Supt. Water Works, Concord, Mass.	Sept. 19, 1900
Hubbell, Clarence W. Water Office, Detroit, Mich.	Sept. 13, 1899
Hughes, V. R., C. E. 610 Betz Bldg., Philadelphia, Pa.	June 12, 1901
Humphreys, W. H. Manager and Chief Engineer York Water Works, Lendal Tower, York, England.	Sept. 9, 1903
Hunking, Arthur W. 374 Stevens Street, Lowell, Mass.	June 11, 1890
Hunt, George C. Water Registrar, Room 19, City Hall, Worcester, Mass.	Sept. 14, 1904
Hunter, T. B. Resident Engineer Pacific Improvement Co.'s Water Works, Monterey, Monterey Co., Cal.	Feb. 8, 1905
Huntington, James A. Water Registrar, Haverhill, Mass.	Dec. 9, 1891
Hyde, Charles G. Asst. Engineer in charge Filtration, Board of Public Works, Harrisburg, Pa.	June 11, 1902
Ince, J. H. Asst. to President of Western New York Water Co., 616 Ellicott Square, Buffalo, N. Y.	Nov. 12, 1902

Name.	Date of Election.
Ingersoll, George I. Supt. Water Works, Schenectady, N. Y.	June 10, 1903
Jackson, Daniel D. Chemist, Division of Water Supply, Mt. Prospect Laboratory, Brooklyn, N. Y.	March 14, 1894
Jackson, William City Engineer, City Hall, Boston, Mass.	June 11, 1890
Janin, George Supt. Montreal Water Works, Montreal, Canada.	Sept. 9, 1903
Johnson, C. H. Exeter, N. H.	Sept. 9, 1903
Johnson, Edward J. City Engineer, Nashua, N. H.	June 11, 1902
Johnson, H. R. Water Commissioner, Reading, Mass.	Dec. 14, 1898
Johnson, William E. Engineer Hartford Board Water Commissioners, West Hartford, Conn.	Sept. 9, 1902
Johnson, William S. Asst. Engineer State Board of Health, Room 140, State House, Boston, Mass.	Jan. 10, 1894
Jones, A. J. New Brunswick, N. J.	Dec. 14, 1887
Jones, James A. Water Registrar, Stoneham, Mass.	March 14, 1894
Jordan, John N. Supt. Water Works, Malden, Mass.	June 12, 1896
Judkins, Fred G. Franklin Falls, N. H.	Feb. 14, 1899
Kay, J. William Supt. Water Works, 75 Congress Street, Milford, Mass.	Jan. 9, 1901
Kent, E. W. Supt. Water Works, Woonsocket, R. I.	Feb. 8, 1893
Kent, Willard Manager Water Co., Narragansett Pier, R. I.	April 21, 1885
Kieran, Patrick Supt. Water Works, Fall River, Mass.	June 16, 1886
Kilbourn, Wm. A. Sec'y (Lancaster) Water Commissioners, South Lancaster, Mass.	Dec. 13, 1899
Killam, James W. Metropolitan Water Works, Reading, Mass.	Dec. 13, 1899
Kimball, Frank C. 14 Beacon Street, Boston, Mass.	Feb. 12, 1896
Kimball, George A. Chief Engineer Elevated Lines, Boston Elevated Railway, 101 Milk Street, Boston, Mass.	June 17, 1887
King, George A. Supt Water Works, Taunton, Mass.	March 11, 1903
Kingman, Horace Supt. Water Works, Brockton, Mass.	June 15, 1893

Name.	Date of Election.
Kinnicutt, Leonard P. 77 Elm Street, Worcester, Mass.	Feb. 8, 1893
Knapp, Louis H. Civil and Hydraulic Engineer, 280 Linwood Avenue, Buffalo, N. Y.	June 17, 1887
Knight, Charles William, C. E. Rome, N. Y.	March 10, 1897
Knudson, A. A. Electrical Engineer, 34 Nassau Street, New York City.	Sept. 11, 1902
Knowles, Morris Engineer Filtration Dept., Pittsburg, Pa.	June 12, 1895
Knowlton, Charles F. Commissioner of Public Works, Quincy, Mass.	Sept. 19, 1900
Koch, Harry G. Supt. Castle Creek Water Co., Aspen, Col.	Dec. 11, 1889
Kuehn, Jacob L. Supt. Water Co., York, Pa.	June 9, 1892
Kuichling, Emil Consulting Engineer, 52 Broadway, Room 1026, New York City.	Sept. 10, 1897
Laforest, J. O. Alfred Chief Engineer Laurentian Water and Power Co., La Presse Building, Montreal, Quebec.	Dec. 14, 1892
Larned, Edward S. South Framingham, Mass.	Jan. 10, 1900
Laurin, James, C. E. 78 Laval Avenue, Montreal, Canada.	Sept. 10, 1903
Lautz, Walter E. Secretary Pekin Water Co., Pekin, Ill.	Sept. 16, 1898
Lawton, Perry Civil Engineer, Savings Bank Building, Quincy, Mass.	Feb. 16, 1894
Lea, R. S. Civil and Hydraulic Engineer, Coristine Building, Montreal, P. Q.	June 15, 1893
Learned, Wilbur F. Civil Engineer, Watertown, Mass.	April 21, 1885
Leitch, W. C. Supt. Montreal Water & Power Co., 135 Abbott Avenue, Westmount, P. Q., Canada.	Sept. 10, 1903
Lesage, Thomas Wm. Asst. Supt. Montreal Water Works, Montreal, Canada.	Sept. 9, 1903
Lisle, Arthur B. Treasurer East Providence Water Co., 170 Westminster Street, Providence, R. I.	Feb. 12, 1902
Lochridge, Elbert E. Engineer Springfield Water Dept., 43 Bridge Street, Springfield, Mass.	Sept. 15, 1904
Locke, James W. Foreman, Brockton, Mass.	Jan. 9, 1895
Lord, Charles S. Secretary and Manager Winooski Aqueduct Co., Winooski, Vt.	June 12, 1901

Name.	Date of Election.
Lord, Harry A. Supt. Water Works, Ogdensburg, N. Y.	Sept. 8, 1897
Loretz, Arthur J. L. Mechanical Engineer, 150 Nassau Street, New York City.	Dec. 9, 1896
Lovell, Thomas C. Supt. Water Works, 104 River Street, Fitchburg, Mass.	June 21, 1882
Luce, Francis H. Supt. Woodhaven Water Supply Co., Woodhaven, N. Y.	June 12, 1896
Ludlow, J. L. 434 Summit Street, Winston, N. C.	Feb. 14, 1900
Lunt, Cyrus M. Supt. Water Works, Lewiston, Me.	Dec. 9, 1896
Lusk, James L. Major Corps of Engineers, U. S. A., U. S. Engineer's office, Rock Island, Ill.	March 13, 1889
Lynch, John W. Engineer for Metropolitan Water Works at Pumping Station, Reservoir, Boulevard Station, Boston, Mass.	Sept. 11, 1902
McCarthy, Daniel B. Supt. Water Works Co., Waterford, N. Y.	Sept. 11, 1895
McClintock, W. E. Member of Massachusetts Highway Commission, 20 Pemberton Square, Boston, Mass.	June 17, 1887
McClure, Frederick A. City Engineer, Worcester, Mass.	June 15, 1894
McConnell, B. D. Division Engineer The Guelph and Goderich Railway Co., Millbank, Ont.	June 12, 1890
McDermott, L. C. Supt. East Orange Water Dept., 26 South Walnut Street, East Orange, N. J.	Dec. 9, 1903
McInnes, Frank A. Asst. Engineer Boston Water Works, 49 City Hall, Boston.	Sept. 18, 1901
McIntosh, H. M. City Engineer, Burlington, Vt.	Sept. 11, 1895
McKenzie, Samuel H. Supt. Water Co., Southington, Conn.	Feb. 11, 1903
McKenzie, Theodore H. Manager Water Works, Southington, Conn.	June 12, 1890
McKenzie, Thomas Supt. Water Works, Box 712, Westerly, R. I.	Dec. 12, 1894
McLean, Hugh Water Commissioner, Holyoke, Mass.	Jan. 13, 1904
MacLean, Thomas A. Charlottetown, P. E. I., Canada.	Jan. 8, 1902
Macksey, H. V. Deputy Supt. Streets, City Hall, Boston, Mass.	Sept. 9, 1902
McMillen, Norman A. Supt. Water Works, North Billerica, Mass.	June 13, 1900
MacMurray, J. C. 33 Oak Avenue, Worcester, Mass.	Dec. 9, 1896

Name.	Date of Election.
Main, Charles T. Mechanical Engineer, 53 State Street, Boston, Mass.	Jan. 11, 1905
Makepeace, D. A. Water Commissioner, Attleboro, Mass.	Dec. 10, 1902
Manley, Samuel C. President and General Manager Maine Water Co., Augusta, Me.	June 10, 1903
Mann, Thomas W. Civil Engineer, Holyoke, Mass.	June 9, 1892
Manning, George E. Civil Engineer, New London, Conn.	March 9, 1898
Marble, Arthur D. City Engineer, Lawrence, Mass.	Feb. 12, 1896
Marple, William M. Chief Engineer Scranton Gas and Water Co., 423 Jefferson Avenue, Scranton, Pa.	Feb. 10, 1904
Martin, A. E. Supt. Water Works, Springfield, Mass.	April 21, 1885
Mason, William P. Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.	Dec. 11, 1895
Mather, Nelson E. Supt. Water Works, Clinton, Mass.	Sept. 19, 1900
Mattice, Asa M. Chief Engineer The Allis-Chalmers Co., Milwaukee, Wis.	June 15, 1894
Maxcy, Josiah S. Treas. Madison Water Co., Gardiner, Me.	Dec. 14, 1887
Maybury, William E. Supt. Water Works, Braintree, Mass.	Jan. 9, 1901
Mayo, John Supt. Water Works, Bridgewater, Mass.	Feb. 10, 1904
Mead, Daniel W. Consulting Engineer, 605 First National Bank Building, Chicago, Ill.	Sept. 19, 1900
Merrill, Andrew S. Supt. Bath and Brunswick Division Maine Water Co., Bath, Me.	Feb. 12, 1902
Merrill, Frank E. Water Commissioner and Supt. Water Works, Somerville, Mass.	Dec. 9, 1896
Merritt, D. S. Engineer and Supt. Water Works, Tarrytown, N. Y.	Dec. 13, 1893
Metcalf, Leonard Civil Engineer, 14 Beacon Street, Boston, Mass.	Feb. 10, 1897
Miller, Hiram A. Chief Engineer Charles River Basin Commission, 367 Boylston Street, Boston, Mass.	March 13, 1901
Miller, John F. Secretary Westinghouse Air Brake Co., Wilmerding, Pa.	June 10, 1896
Miller, Joseph T. Secretary Pennsylvania Water Co., Edgewood, Allegheny County, Pa.	Sept. 9, 1902

Name.	Date of Election.
Miller, P. Schuyler 108 Park Place, Brooklyn, N. Y.	Jan. 10, 1900
Mills, Frank H. City Engineer Woonsocket, R. I.	Jan. 14, 1891
Mixer, Charles A. Resident Engineer Rumford Falls Light and Water Co., Rumford Falls, Me.	Sept. 18, 1901
Moat, C. P. Burlington, Vt.	March 13, 1901
Molis, William Supt. Water Works Co., Muscatine, Iowa.	June 17, 1887
Moore, Fred F. 129 Prospect Place, Brooklyn, N. Y.	Jan. 14, 1903
Moran, John W. Supt. Water Works, Gloucester, Mass.	March 13, 1901
Mullhall, John F. J. Treasurer Portland (Conn.) Water Co., 14 Beacon Street, Boston, Mass.	Nov. 14, 1900
Murdoch, William Supt. Water Works, St. John, N. B.	Jan. 10, 1900
Myers, J. H., Jr. Asst. Engineer N. Y. Rapid Transit R. R. Commission, 1034 Forest Avenue, Bronx, New York City.	Sept. 11, 1895
Nash, H. A., Jr. Civil Engineer, Weymouth Heights, Mass.	March 13, 1895
Nettleton, Charles H. Treasurer and Supt. Water Co., Birmingham, Conn.	June 16, 1886
Nichols, Thomas P. Member Water Board, 11 Prospect Street, Lynn, Mass.	Jan. 10, 1894
Northrop, Frank L. 220 Franklin Street, Boston, Mass.	June 15, 1893
Nuebling, Emil L. Engineer and Supt. Water Dept., Reading, Pa.	Feb. 12, 1896
Nye, Joseph K. President Water Company, Fairhaven, Mass.	March 8, 1893
Nye, S. A. Trustee Kennebec Water District, Fairfield, Me.	Feb. 10, 1904
O'Connell, P. D. Supt. Water Works, Somersworth, N. H.	Sept. 16, 1898
Paine, C. W. Civil Engineer, Highland, Cal.	Dec. 12, 1888
Palmer, Augustus B. Supt. Water Co., Franklin, Mass.	Sept. 14, 1904
Parker, Horatio N. U. S. Geological Survey, Washington, D. C.	March 10, 1897
Parks, Oren E. City Engineer, Westfield, Mass.	March 9, 1904
Parmelee, Charles L. 136 Liberty Street, New York City.	March 11, 1903
Parsons, H. D. Supt. Westfield Water Works, 12 Bush Street, Westfield, Mass.	Sept. 14, 1904

Name.	Date of Election.
Patch, Walter W. Civil Engineer, Rudolph Terrace, Yonkers, N. Y.	June 12, 1895
Paulison, Washington Supt. Acquackanonk Water Co., Passaic, N. J.	Sept. 16, 1898
Payson, E. R. Secretary Portland Water Co., Portland, Me.	June 13, 1900
Pease, A. G. Water Commissioner, Spencer, Mass.	June 16, 1886
Peck, Erman M. Distribution Engineer Hartford Water Works, 972 Farmington Avenue, West Hartford, Conn.	Nov. 11, 1903
Peene, Edward L. Supt. Water Works, Yonkers, N. Y.	Sept. 16, 1898
Peirce, Charles E. Supt. East Providence Water Co., East Providence Centre, R. I.	Sept. 14, 1887
Perkins, Clarence A. Chairman Water Board, Malden, Mass.	June 11, 1902
Perkins, John H. Supt. Watertown and Belmont Water Works, Watertown, Mass.	June 16, 1886
Perkins, W. C. 2 Webster Street, Brookline, Mass.	Dec. 10, 1902
Perry, Henry E. Supt. Water Works, Dover, N. H.	Dec. 9, 1903
Phelps, Earle B. Bacteriologist and Chemist, Sanitary Research Laboratory, Mass. Institute of Technology, Boston, Mass.	Feb. 11, 1903
Pickup, A. E. Water Registrar, Holyoke, Mass.	Jan. 13, 1904
Pierce, Frank L. 43 East 27th Street, New York City, N. Y.	Dec. 14, 1898
Pitcher, Frank H. Chief Engineer Montreal Water and Power Co., 62 Imperial Building, St. James Street, Montreal, P. Q.	June 12, 1901
Pitman, Winthrop M. Treasurer North Conway Water and Improvement Co. Address, 493 Centre Street, Jamaica Plain, Mass.	June 17, 1887
Pitney, Frederic V. Engineer Morristown Aqueduct Co., Morristown, N. J.	Feb. 16, 1894
Points, Joseph D. Supt. Water Works, Palatka, Fla.	Sept. 9, 1903
Pollard, William D. General Manager Water Co., Pottsville, Pa.	June 10, 1891
Porter, Dwight Professor of Hydraulic Engineering, Massachusetts Institute of Technology, Boston, Mass.	March 13, 1889
Potter, Alexander Civil and Sanitary Engineer, 143 Liberty Street, New York City.	March 14, 1894
Probst, C. O. Secretary State Board of Health, Columbus, Ohio.	Dec. 8, 1897

Name.	Date of Election.
Putnam, J. B. Supt. Westboro Water and Sewer Depts., Westboro, Mass.	Sept. 10, 1897
Raymond, William G. Iowa City, Iowa.	March 12, 1902
Rice, George S. Deputy Chief Engineer Rapid Transit Railroad Commissioners, 320 Broadway, New York City.	Dec. 14, 1892
Rice, James L. Supt. Water Co., Claremont, N. H.	June 15, 1894
Rice, L. Frederick Architect and Civil Engineer, 125 Milk Street, Boston, Mass.	June 17, 1887
Richards, Walter H. Supt. Water Works, New London, Conn.	Oct. 11, 1882
Richardson, T. F. Dept. Engineer Metropolitan Water Works, Clinton, Mass.	Feb. 10, 1897
Ricker, Guy W. Civil Engineer, Salem, Mass.	March 11, 1903
Riley, Charles E. Member Water Board, Brookline, Mass.	Sept. 13, 1899
Robbins, F. H. Civil Engineer, Dept. of Filtration, Pittsburg, Pa.	Sept. 10, 1897
Robertson, George H. Supt. Water Works, Yarmouth, N. S.	June 9, 1892
Robertson, W. W. Water Registrar, Fall River, Mass.	June 17, 1887
Robinson, J. S. Supt. Columbia Water & Light Co., Columbia, Tenn.	June 10, 1903
Robinson, Leonard C. East Sumner, Me.	Sept. 14, 1904
Roden, Thomas Supt. Water Works, Arlington, Mass.	June 12, 1896
Roullier, G. A. Supt. Water Works, Flushing, N. Y.	June 13, 1889
Royce, Harley E. Asst. Engineer, Brookline, Mass.	Jan. 9, 1895
Russell, A. N. President Water Commissioners, Ilion, N. Y.	Sept. 13, 1899
Safford, Arthur T. Asst. Engineer Props. Locks and Canals, 66 Broadway, Lowell, Mass.	Feb. 11, 1902
Sanborn, George A. Supt. Essex Company of Lawrence, 221 Bruce Street, Lawrence, Mass.	Nov. 12, 1902
Sando, W. J. Manager Water Works Dept., International Steam Pump Co., Pfister Hotel, Milwaukee, Wis.	June 12, 1895
Saville, Caleb M. Engineering Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Scott, Walter M. P. O. Box 321, New Glasgow, N. S.	Nov. 13, 1901

Name.	Date of Election.
Scranton, Worthington Asst. to President Scranton Gas and Water Co., Scranton, Pa.	Dec. 9, 1903
Sears, Walter H. Katonah, Westchester Co., N. Y.	Sept. 13, 1899
Sealy, W. F. P. Supt. Water Works, Potsdam, N. Y.	Sept. 13, 1895
Senior, Samuel P. Engineer and Supt. Bridgeport Hydraulic Co., 323 Water Street, Bridgeport, Conn.	March 12, 1902
Sharpe, C. Dwight Supt. Water Co., Putnam, Conn.	Sept. 13, 1903
Sharples, Philip P. 22 Concord Avenue, Cambridge, Mass.	June 14, 1899
Shaw, Jesse W. Inspector Hingham Water Co., Hingham, Mass.	Sept. 9, 1903
Shedd, Edward M. Inspector Water Works, Somerville, Mass.	Jan. 9, 1901
Shedd, Edward W. Civil Engineer, 146 Westminster Street, Providence, R. I.	March 9, 1892
Shedd, J. Herbert Consulting Engineer, Providence, R. I.	June 13, 1888
Sherman, Charles W. Assistant Manager Water Co.'s, 14 Beacon Street, Boston, Mass.	Sept. 10, 1897
Sherman, William B. Mechanical Engineer, 45 Elmwood Avenue, Providence, R. I.	Oct. 11, 1882
Sherrerd, Morris R. Engineer Water Dept., Newark, N. J.	March 10, 1897
Sinclair, Melville A. Supt. Water Works, Bangor, Me.	June 15, 1894
Smith, E. G. Chemist, Beloit, Wis.	Sept. 14, 1904
Smith, Herbert E. Professor of Chemistry, Yale Medical School; Chemist Connecticut State Board of Health. Address, 430 George Street, New Haven, Conn.	Dec. 14, 1892
Smith, H. O. Water Commissioner, Leicester, Mass.	June 15, 1894
Smith, John E. Supt. Water Works, Andover, Mass.	June 10, 1896
Smith, J. J. City Engineer, Grand Forks, N. D.	Nov. 14, 1900
Smith, J. Waldo Chief Engineer Croton Aqueduct, New York City.	Dec. 13, 1893
Smith, Phil S. Supt. Water Dept., Montpelier, Vt.	Sept. 9, 1903
Smith, Sidney Civil Engineer, 91 Maple Street, West Roxbury, Mass.	June 12, 1895
Smith, Solon F. Supt. and Treas. Water Co., Grafton, Mass.	June 17, 1887

Name.	Date of Election
Snell, George H. Water Commissioner and Supt. Water Works, Attleboro, Mass.	Dec. 12, 1900
Soper, George A. 29 Broadway, New York City.	Jan. 12, 1898
Souther, Henry Water Commissioner, Hartford, Conn.	June 13, 1900
Sparks, H. T. Supt. Water Dept., Public Works Co., Bangor, Me. Address, Box 208, Brewer, Me.	June 15, 1894
Spooner, Herman W. Engineer Gloucester Water Works, 28 Granite Street, Gloucester, Mass.	Nov. 13, 1901
Sprenkel, John F. General Manager York Water Co., York, Pa.	June 12, 1901
Springfield, John F. General Manager Ottumwa Traction & Light Co., Ottumwa, Iowa.	Jan. 13, 1892
Stacy, George A. Supt. Water Works, Marlboro, Mass.	April 21, 1885
Staples, George T. Supt. Water Works, Dedham, Mass.	June 11, 1902
Stearns, Frederic P. Chief Engineer Metropolitan Water and Sewerage Board, 1 Ashburton Place, Boston, Mass.	June 17, 1887
Stearns, S. A. Supt. Granite City Water Works, Granite City, Ill.	Sept. 9, 1903
Stevens, James T. Chairman Board of Water Commissioners, South Braintree, Mass.	Jan. 8, 1902
Stevenson, Harry W. Wildwood Pumping Station, Nadine, Allegheny County, Pa.	Sept. 21, 1900
Stone, Charles A. Electrical Engineer, 84 State Street, Boston, Mass.	June 15, 1894
Street, L. Lee 27 Pearl Street, Dorchester, Mass.	Jan. 10, 1900
Sullivan, J. J. Water Commissioner, Holyoke, Mass.	March 9, 1898
Sullivan, T. V. General Foreman Meter Service, Boston Water Dept., 1413 Washington Street, Boston, Mass.	March 9, 1904
Sullivan, William F. City Engineer's Office, Lowell, Mass.	Feb. 14, 1900
Swain, George F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.	June 17, 1887
Taber, George A. Asst. to Chief Engineer, Dept. Water Supply, Park Row Bldg., New York City.	Dec. 9, 1903
Taber, Robert W. Water Commissioner, New Bedford, Mass.	Sept. 16, 1898

Name.	Date of Election.
Taubenheim, Ulrich E. Manager City Water Works, Archangel, Russia.	Sept. 14, 1904
Taylor, Charles N. Contracting Engineer, Wellesley, Mass.	Feb. 13, 1901
Taylor, Edwin A. Constructing Engineer, Uxbridge, Mass.	Dec. 14, 1892
Taylor, Fred I. Supt. Water Works, Westboro Insane Hospital, Westboro, Mass.	Sept. 9, 1902
Taylor, Lucian A. Civil Engineer and Contractor, 73 Tremont Street, Boston, Mass.	June 19, 1884
Thayer, Dr. F. C. Trustee Kennebec Water District, Waterville, Me.	Feb. 10, 1904
Thomas, Robert J. Supt. Water Works, Lowell, Mass.	June 9, 1892
Thomas, Harry L. Asst. Supt. Water Co., Hingham, Mass.	Dec. 14, 1898
Thomas, William H. Supt. Water Co., Hingham, Mass.	Dec. 14, 1887
Thomson, John Hydraulic Engineer, 253 Broadway, New York City.	June 9, 1892
Thorpe, Lewis D. 28 Gleason Street, West Medford, Mass.	Feb. 10, 1904
Tighe, James L. Engineer Water Works, Holyoke, Mass.	March 9, 1898
Tinkham, S. Everett Asst. Engineer Engineering Dept., City Hall, Boston, Mass.	Jan. 14, 1891
Tompkins, Charles H. Civil Engineer, 120 Liberty Street, New York City.	Dec. 11, 1889
Tower, D. N. Supt. Water Co., Cohasset, Mass.	June 17, 1887
Trautwine, J. C., Jr., 257 S. Fourth Street, Philadelphia, Pa.	Nov. 9, 1904
Travis, George W. Supt. Water Works, Natick, Mass.	Dec. 13, 1899
Treman, E. M. Supt. and Secretary Water Co., Ithaca, N. Y.	June 11, 1890
Tribus, Louis L. Consulting Civil and Hydraulic Engineer, 84 Warren Street, New York City.	March 11, 1896
Tubbs, J. Nelson General Inspector Dept. of Public Works, State of New York, 207 Wilder Building, Rochester, N. Y.	June 11, 1890
Turner, H. N. Manager Water Co., St. Johnsbury, Vt.	Dec. 11, 1895
Tuttle, Arthur S. Civil Engineer Department Water Supply, 82d Street, near 11th Avenue, Brooklyn, N. Y.	March 14, 1894
Vanier, J. Emile 5 Beaver Hall Square, Montreal, Canada.	March 9, 1904

Name.	Date of Election.
Van Keuren, Charles A. Chief Engineer Jersey City Water Works, Jersey City, N. J.	Feb. 8, 1905
Vaughn, W. H. Supt. Water Works, Wellesley Hills, Mass.	Dec. 11, 1889
Venner, John Chief Inspector Bureau of Water, Syracuse, N. Y.	Jan. 11, 1899
Volkhardt, William Supt. The Crystal Water Co., of Edgewater, Stapleton, N. Y.	Jan. 14, 1903
Vrooman, Morrell City Engineer, Gloversville, N. Y.	Feb. 11, 1902
Walker, Charles K. Supt. Water Works, Manchester, N. H.	June 21, 1882
Wallace, E. L. Supt. Water Works, Franklin Falls, N. H.	Dec. 14, 1892
Walsh, Redmond E. Water Registrar, Woburn, Mass.	March 9, 1904
Warde, Charles S. Cashier Staten Island Water Supply Co., West New Brighton, Staten Island, N. Y.	Sept. 18, 1901
Warde, John S. Supt. Staten Island Water Supply Co., West New Brighton, Staten Island, N. Y.	June 15, 1894
Webster, F. P. Supt. Water Works Co., Lakeport, N. H.	Jan. 8, 1890
Wegmann, E. 70 Fisher Avenue, White Plains, N. Y.	June 12, 1901
West, George F. Manager Water Works, Union Mutual Building, Portland, Me.	Nov. 13, 1901
Weston, Robert S. Chemist and Bacteriologist, 14 Beacon Street, Boston, Mass.	Sept. 8, 1897
Wetherbee, W. J. Supt. and Registrar Water Works, Leominster, Mass.	June 10, 1903
Wheeler, Elbert Treasurer Water Co., 14 Beacon Street, Boston, Mass.	Dec. 9, 1891
Wheeler, William Civil Engineer, 14 Beacon Street, Boston, Mass.	Dec. 11, 1889
Whipple, George C. 220 Broadway, New York City.	Feb. 8, 1893
Whitham, Jay M. Mechanical Engineer, 607 Bullitt Building, Philadelphia, Pa.	Dec. 13, 1893
Whitney, John C. Water Commissioner, Newton, Mass.	June 17, 1887
Whittemore, W. P. Supt. Electric Light and Water Depts., North Attleboro, Mass.	June 16, 1886
Wiggin, Thomas H. 753 Mellon Street, Pittsburg, Pa.	June 11, 1902
Wilber, L. J. Engineer Sewerage Pumping Station, Campello, Mass.	March 11, 1903
Wilde, George E. Asst. Supt. Metropolitan Water Works, Medford, Mass.	June 16, 1886

Name.	Date of Election.
Wilder, Frederick W. Treasurer Aqueduct Co., Woodstock, Vt.	Dec. 12, 1888
Wilkins, Frank B. Supt. Water Works, Milford, N. H.	Feb. 14, 1900
Williams, Gardner S. Engineer in charge of Hydraulic Laboratory, and Professor of Experimental Hydraulics, 1503 Washtenaw Avenue, Ann Arbor, Mich.	June 12, 1895
Williams, Henry J. Chemical Engineer, 161 Tremont Street, Boston, Mass.	Jan. 11, 1905
Williams, William F. City Engineer, New Bedford, Mass.	Feb. 16, 1894
Winslow, C.-E. A. Massachusetts Institute of Technology, Boston, Mass.	Sept. 21, 1900
Winslow, Frederic I. Asst. Engineer, City Engineer's Office, City Hall, Boston, Mass.	Jan. 13, 1892
Winslow, George E. Waltham, Mass.	June 18, 1885
Winsor, Frank E. Div. Engineer Charles River Basin Commission, 367 Boylston Street, Boston, Mass.	Sept. 14, 1904
Wiswall, E. T. West Newton, Mass.	June 13, 1889
Witherell, Frederick W. Am. Water Works and Guarantee Co., Pittsburg, Pa.	June 11, 1902
Wood, Henry B. Harbor and Land Commission, State House, Boston, Mass.	Dec. 13, 1893
Wood, Leonard P. Asst. Engineer Charles River Basin Commission, 367 Boylston Street, Boston, Mass.	Sept. 14, 1904
Wooding, Charles L. Manager Bristol Water Co., Bristol, Conn.	Feb. 8, 1905
Woodruff, Timothy Supt. Water Works, Bridgeton, N. J.	June 13, 1888
Woodward, A. E. Chief Engineer Wolverhampton Water Works, Wolverhampton, England.	Sept. 9, 1903
Woods, Henry D. West Newton, Mass.	Jan. 9, 1895
Woods, L. R. Supt. Water Dept., 206 Vine Street, Everett, Mass.	Sept. 18, 1901
Worthington, E., Jr. Civil Engineer, Dedham, Mass.	Jan. 11, 1893
Wright, George W. Chief Engineer, Water Dept., Norfolk, Va.	June 9, 1892
Wyman, W. S. 24 Pleasant Street, Waterville, Me.	Feb. 12, 1902
Wynne-Roberts, R. O. Water Engineer, Cape Town, South Africa.	Nov. 12, 1902
Yorston, W. G. Town Engineer, Sydney, N. S.	Dec. 14, 1892
Ziek, W. G. 253 Broadway, New York City.	June 15, 1893

HONORARY MEMBERS.

NAME.	Date of Election.
Bryan, William Booth Chief Engineer Metropolitan Water Board, London, England.	Sept. 14, 1904
Croes, J. J. R., C. E. 68 Broad Street, Morris' Building, New York City.	Sept. 14, 1904
FitzGerald, Desmond Brookline, Mass.	Sept. 14, 1904
Frost, George H. President Engineering News Pub. Co., St. Paul Building, New York City.	June 16, 1886
Hermany, Charles Chief Engineer and Supt. Water Works, Louisville, Ky.	Sept. 14, 1904
Meyer, Henry C. 114 Liberty Street, New York City.	June 17, 1887
Sedgwick, William T. Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.	Sept. 14, 1904
Shepperd, F. W. *Fire and Water*, Bennett Building, Nassau and Fulton Streets, New York City.	Feb. 12, 1890

ASSOCIATES.

Allis-Chalmers Co. High Duty Pumping Engines, Milwaukee, Wis.	Dec. 13, 1893
Ashton Valve Co. Water Relief Valves, 271 Franklin Street, Boston, Mass.	June 18, 1885
Bard Union Co., The Norwich, Conn.	Sept. 15, 1904
Barker, Roy S. Treas. Barker Well Co., 141 Allens Avenue, Providence, R. I.	Feb. 8, 1905
Harold L. Bond & Co. Construction Work Supplies, 140 Pearl Street, Boston, Mass.	Dec. 12, 1900
Builders Iron Foundry P. O. Box 218, Providence, R. I.	June 17, 1887
J. B. Campbell Brass Works 16th and Cascade Streets, Erie, Pa.	Sept. 18, 1901
Chadwick-Boston Lead Co. 162 Congress and 180-182 Franklin Streets, Boston, Mass.	April 21, 1885
Chapman Valve Mfg. Co. Valves and Hydrants, Indian Orchard, Mass.	June 21, 1883
Charles A. Claflin & Co. Steam Engineering and Water Works Supplies, 50 High Street, Boston, Mass.	Jan. 9, 1901
Coffin Valve Co. Valves and Hydrants, Neponset, Boston, Mass.	June 16, 1886
Desper, Henry A. Worcester, Mass.	Sept. 14, 1904
Drummond, M. J. Cast Iron Pipe, 192 Broadway, Corbin Building, New York City.	Dec. 14, 1887
Eagle Oil and Supply Co. 104 Broad Street, Boston, Mass.	June 15, 1894

Name.	Date of Election.
Fairbanks Co., The 38–44 Pearl Street, Boston, Mass.	Sept. 15, 1904
Gallison, William H. Co. Engineers' Supplies, Pipe, etc., 36 Oliver Street, Boston, Mass.	June 18, 1885
Garlock Packing Co. 43 High Street, Boston, Mass.	June 11, 1896
Gifford, Fred C. Manufacturer of Tools and Supplies, 21 Crescent Street, Waltham, Mass.	Sept. 9, 1903
George E. Gilchrist Co. Manufacturers and Jobbers of Steam, Gas and Plumbing Material, 106 High Street, Boston, Mass.	Dec. 14, 1904
Greenwood, William H. 220 Franklin Street, Boston, Mass.	Sept. 11, 1902
Hart Packing Co. Manufacturers of Steam and Water Packing, 145 High Street, Boston, Mass.	Jan. 13, 1904
Hays Mfg. Co. Erie, Pa.	Sept. 15, 1904
Hersey Mfg. Co. Water Meters, South Boston, Mass.	June 16, 1886
Thomas Hoey Supply and Mfg. Co. 405 Atlantic Avenue, Boston, Mass.	Feb. 12, 1902
International Steam Pump Co. 114 Liberty Street, New York City.	June 12, 1901
Jenkins Bros. Pumps, Valves, etc., 35 High Street, Boston, Mass.	Sept. 9, 1902
Kennedy Valve Co. Valves, Hydrants, and Indicating Devices, 57 Beekman and 87 Ann Streets, New York City.	Sept. 8, 1897
Lead Lined Iron Pipe Co. Lead and Tin Lined Pipe, Wakefield, Mass.	Sept. 8, 1897
Ludlow Valve Mfg. Co. Valves and Hydrants, 150 High Street, Boston, Mass.	June 18, 1885
Lynch, John E. Proprietor E. Hodge & Co., Stand Pipes, East Boston, Mass.	June 10, 1891
Montreal Pipe Foundry Co., Ltd. Acadia Mines, Londonderry, N. S.	Jan. 8, 1902
Mueller, H., Mfg. Co. Water Works Supplies, Decatur, Ill.	Sept. 11, 1895
National Lead Co. (Boston Branch) 89 State Street, Boston, Mass.	March 14, 1894
National Meter Co. Meters, 84 Chambers Street, New York City.	Oct. 11, 1882
Neptune Meter Co. Trident Water Meters, Jackson Avenue and Crane Street, Long Island City, N. Y.	June 15, 1893
New York Continental Jewell Filtration Co. Filters, 15 Broad Street, New York City.	June 15, 1894
Norwood Engineering Co. Hydrants, Filters, etc., Florence, Mass.	April 21, 1885

Name.	Date of Election.
Perrin, Seamans & Co. Construction Tools and Supplies, 57 Oliver Street, Boston, Mass.	June 11, 1890
Pittsburg Meter Co. Water Meters, East Pittsburg, Pa.	June 15, 1894
Platt Iron Works Co., The 73 Oliver Street, Boston, Mass.	Sept. 9, 1902
Rea, William M. Representing A. W. Chesterton & Co., Combination Packing, 64 India Street, Boston, Mass.	Sept. 9, 1903
Rensselaer Mfg. Co. Valves and Water Gates, and Sole Manufacturers of Corey Fire Hydrant, Troy, N. Y.	June 11, 1890
Roberts, C. E. Hartford Steam Boiler Inspection and Insurance Co., 101 Milk Street, Boston, Mass.	March 13, 1889
Ross Valve Co. Troy, N. Y.	June 13, 1888
Sampson, George H. Powder, 13 Pearl Street, Boston, Mass.	June 18, 1885
Schumacher, G. 2d Vice-President Central Foundry Co., Manufacturers, Universal Cast Iron Water Pipes, 116 Nassau Street, New York City.	Sept. 9, 1903
Smith, A. P. Mfg. Co. Tapping Machines, Passaic Avenue, foot of Brill Street, Newark, N. J.	Feb. 10, 1892
Sumner & Goodwin Co. Water Works Supplies, 287 Congress Street, Boston, Mass.	April 21, 1885
Sweet & Doyle Selling Agents Vincent Valves, Cohoes, N. Y.	June 13, 1900
Thomson Meter Co. Water Meters, 79 Washington Street, Brooklyn, N. Y.	June 13, 1888
Tod, The William Company Builders of High Duty Pumping Engines, Youngstown, Ohio.	Feb. 10, 1904
Union Water Meter Co. 31 Hermon Street, Worcester, Mass.	June 21, 1883
United States Cast Iron Pipe and Foundry Co. Corner Broad and Chestnut Streets, Philadelphia, Pa.	Sept. 13, 1899
Waldo Bros. Contractors' Supplies, 102 Milk Street, Boston, Mass.	April 21, 1885
Walworth Mfg. Co. Pipe, Brass Work, Service Boxes, etc., 134 Federal Street, Boston, Mass.	April 21, 1885
Wood, R. D. & Co. Cast Iron Pipe, 400 Chestnut Street, Philadelphia, Pa.	June 19, 1884

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4